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(54) Method and system for providing protected mode device drivers.

(57) A computer method and system for providing protected mode device drivers that are compatible with real mode device drivers. A first aspect of the invention provides consistent assignment of drive unit numbers with which the same physical disks are accessed by the real mode and protected mode physical disk drivers. A second aspect of the invention provides consistent assignment of volume unit numbers with which the same logical volumes are accessed by real mode and protected mode logical volume drivers. A third aspect of the invention provides consistent assignment of adapter numbers with which the same adapters are controlled by real mode and protected mode adapter drivers and mapping real mode adapter driver requests to protected mode adapter driver requests of the protected mode adapter drivers that control the same adapters. A fourth aspect of the invention provides detection and protected mode accommodation of real mode functional drivers which are provided in addition to the real mode device drivers in the real mode operating system.

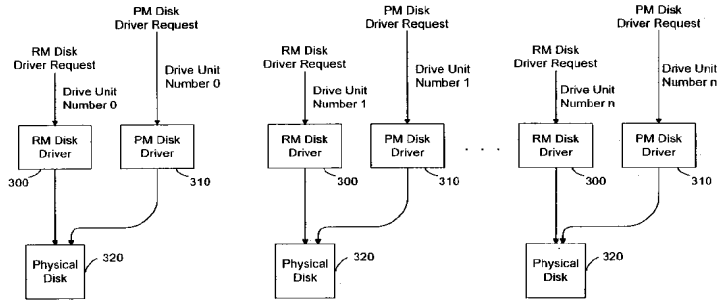

FIG. 3

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Technical Field

The present invention relates to the field of device drivers and, more particularly, to an operating system which provides protected mode device drivers.

Background of the Invention

A typical computer system includes a computer that is interfaced with a number of peripheral devices. The peripheral devices can be accessed by an operating system executing on the computer or by application programs executing on the computer via an appropriate interface. Such access to the devices is controlled by software programs known as device drivers. Many device drivers, such as those provided by the Microsoft MS-DOS operating system, are "real mode device drivers" which operate in a processor mode known as real mode. Real mode is the only mode of operation provided by the Intel 8086 microprocessor, on which the Microsoft MS-DOS operating system was originally designed to execute.

More recent microprocessors such as the Intel 80826, 80386 and 80486, sold by Intel Corporation of Cupertino, California, are upwardly compatible with the 8086 and thus are designed to support real mode but they may also operate in an enhanced mode, known as "protected mode". Protected mode provides benefits not provided by real mode. For instance, protected mode provides an enlarged virtual address space than provided by real mode. Protected mode also provides hardware support for multitasking and data security, which real mode does not. (The protection mechanism which provides data security in the 80386 and 80486 is described in pp. 101-133 of "Microsoft's 80386/80486 Programming Guide," published by Microsoft press, 1991.)

Summary of the Invention

The present invention provides protected mode device drivers which are compatible with real mode device drivers that access the same device. The protected mode device drivers are compatible with the real mode device drivers in the sense that they use the same reference values to access the same devices. In a preferred embodiment, the invention provides an operating system capable of operating in protected mode and having the protected mode device drivers. During operation of the operating system in protected mode, the protected mode device drivers access the devices when so requested by the operating system or an application program. Real mode device drivers are also provided which access the devices in real mode when requested by an operating system or application program that requires real mode operation. The protected mode device drivers assign the same reference values to the devices as the real mode device drivers assign to the same devices. The invention ensures compatibility with respect to these reference values by providing multiple aspects of the invention, which are described below.

A first aspect of the invention provides consistent assignment of drive unit numbers with which the same physical disks are accessed by real mode and protected mode disk drivers. The real mode disk drivers which access physical disks may not assign the same drive unit numbers to those physical disks as the protected mode disk drivers which access the same physical disks. The problem is that real mode disk drivers may have different drive numbers than the drive numbers assigned to corresponding protected mode disk drivers for BIOS INT 13h interrupts. In the first aspect of the invention, the preferred embodiment provides consistent assignment of the drive unit numbers with which the same physical disks are accessed via INT 13h interrupts by both the real mode and protected mode physical disk drivers. As a result, access to the same physical disks is provided by both the real mode disk drivers and protected mode disk drivers in a compatible fashion.

A second aspect of the invention provides consistent assignment of logical volume unit numbers with which the same logical volumes are accessed by real mode and protected mode volume drivers. The real mode volume drivers which control access to logical volumes on disks may not assign the same volume unit numbers to those logical volumes as the protected mode volume drivers which control access to the same logical volumes. Specifically, the real mode volume drivers may have different volume numbers than the volume numbers assigned to corresponding protected mode volume drivers for BIOS INT 25h interrupts. In the second aspect of the invention, the preferred embodiment provides consistent assignment of the volume unit numbers with which the same logical volumes are accessed via INT 25h interrupts by both the real mode and protected mode logical volume drivers. Thus, access to the same logical volumes is provided by both the real mode volume drivers and protect mode volume drivers.

A third aspect of the invention provides consistent assignment of adapter numbers with which the same adapters are controlled by real mode and protected mode adapter drivers to access the peripheral devices

connected to those adapters. The real mode adapter drivers which access peripheral devices via adapters may not assign the same adapter numbers to those adapters as the protected mode operating system assigns to protected mode adapter drivers that control the same adapters to access the same peripheral devices. In the third aspect of the invention, the preferred embodiment provides consistent assignment of the adapter numbers with which the same adapters are controlled by both the real mode and protected mode adapter drivers to access the same peripheral devices. The third aspect of the invention further provides mapping of requests to access the peripheral devices via real mode adapter drivers to requests to access the peripheral devices via protected mode adapter drivers which control the same adapters. Requests by application programs to access the peripheral devices may be directed to the real mode adapter drivers even during operation of the protected mode operating system unless otherwise directed. The preferred embodiment provides mapping of application program requests to access the peripheral devices via real mode adapter drivers to requests to access the peripheral devices via protected mode adapter drivers which control same adapters.

The preferred embodiment further provides protected mode operation of functions provided by real mode functional devices when the real mode device drivers are executed. Thus, a fourth aspect of the invention provides detection and protected mode accommodation of real mode functional drivers which have been provided in addition to the real mode device drivers. Real mode functional drivers may have been added to supplement the real mode device drivers by providing additional functions. These functions may or may not be provided by any protected mode functional drivers in the protected mode operating system. Unless these real mode functional drivers are accommodated by the operating system when operating in protected mode, the protected mode device drivers will be incompatible with the real mode device drivers. In the fourth aspect of the invention, the preferred embodiment provides detection and protected mode accommodation of the real mode functional drivers that are provided in addition to the real mode device drivers in the real mode operating system. As a result of providing the above four aspects of the invention, the preferred embodiment provides protected mode device drivers which are compatible with real mode device drivers and yet still reap the benefits of protected mode operation.

Brief Description of the Drawings

Figure 1 is a block diagram of a typical computer system in which a computer is connected to disk drives and other peripheral devices.

Figure 2 is an illustration of the functional relationship among the real mode and protected mode device drivers and functional drivers and the devices which they control.

Figure 3 is an illustration of the functional relationship among the real mode disk drivers and protected mode disk drivers of the preferred embodiment of the present invention.

Figure 4 is a flow diagram of the process of creating a drive table in the preferred embodiment.

Figure 5 is an illustration of the process of creating a drive table in the contents of a portion of a master boot record of a disk in the preferred embodiment.

Figure 6 is an illustration of the drive table created in the preferred embodiment.

Figure 7 is a flow diagram of the process of assigning a drive unit number in the preferred embodiment.

Figure 8 is an illustration of the functional relationship among the real mode volume drivers and protected mode volume drivers of the preferred embodiment.

Figure 9 is a flow diagram of the process of building a volume table in the preferred embodiment.

Figure 10 is an illustration of a partition boot record and volume boot record of a volume on a disk in the preferred embodiment.

Figure 11 is an illustration of the volume table created in the preferred embodiment.

Figure 12 is a flow diagram of the process of assigning a volume unit number in the preferred embodiment.

Figure 13 is an illustration of the real mode adapter drivers and protected mode adapter drivers of the preferred embodiment.

Figure 14 is a flow diagram of the process of building a real mode data structure in the preferred embodiment.

Figure 15 is an illustration of the real mode data structure created in the preferred embodiment and unit specifies associated with each real mode data structure.

Figure 16 is an illustration of peripheral data in each unit specifier created in the preferred embodiment.

Figure 17 is a flow diagram of the process of creating data control blocks in the preferred embodiment.

Figure 18 is an illustration of the data control block created in the preferred embodiment.

Figure 19 is a flow diagram of the process of assigning adapter numbers in the preferred embodiment.

Figure 20 is a flow diagram of the process of accommodating real mode functional drivers in the preferred embodiment.

Figure 21 is a flow diagram of the process of detecting a real mode functional driver in the preferred embodiment.

Figure 22 is an illustration of a data parameter block, the contents of a portion thereof and the real mode device drivers or functional drivers specified therein.

Figure 23 is an illustration of an original driver structure in the preferred embodiment.

Figure 24 is an illustration of a safe driver list in the preferred embodiment.

Figure 25 is a flow diagram of the process of adapting a real mode functional driver in the preferred embodiment.

Detailed Description of the Invention

The preferred embodiment of the present invention substitutes protected mode device drivers for real mode device drivers whenever possible. The protected mode device drivers are implemented to be compatible with the real mode device drivers. Specifically, the protected mode device drivers access devices are assigned reference values that identify the same devices in the same fashion as the real mode device drivers. The preferred embodiment further provides, to the extent possible, protected mode operation of functions provided by real mode functional devices when the real mode device drivers are executed.

The above features are provided by four separate aspects of the invention, described below. A first aspect of the invention provides consistent assignment of drive unit numbers with which the same physical disks are accessed by real mode and protected mode disk drivers. A second aspect of the invention provides consistent assignment of logical volume unit numbers with which the same logical volumes are accessed by real mode and protected mode volume drivers. A third aspect of the invention provides consistent assignment of adapter numbers with which the same adapters are controlled by real mode and protected mode adapter drivers to access the peripheral devices connected to those adapters. The third aspect of the invention further provides mapping of requests to access the peripheral devices via real mode adapter drivers to requests to access the peripheral devices via protected mode adapter drivers which control the same adapters. A fourth aspect of the invention provides detection and protected mode accommodation of real mode functional drivers which are provided in addition to the real mode device drivers.

A computer system suitable for practicing the preferred embodiment of the present invention is shown in Figure 1. Figure 1 is a block diagram of a computer system having a computer 100 coupled to disk drives 110 and peripheral devices 120. The computer 100 has an internal memory 102 which stores an operating system 210. The memory 102 also stores real mode and protected mode device drivers. These drivers may be part of the operating system 210 or separate from the operating system. The device drivers are run on a central processing unit (CPU) 104 to control access to the devices 110 and 120 as requested by the operating system 210 or by an application program. The device drivers include disk drivers and volume drivers which control the disk drives 110 via an I/O controller 106. The device drivers for the disks allow access to the physical disks and logical volumes on disks resident on the disk drives 110. The device drivers also include adapter drivers which control the adapters 108 through which the peripheral devices 120 are accessed. The memory 102 also stores real mode and protected mode functional drivers which are executed by the CPU 104 to add functional enhancements to the device drivers, such as encryption and data compression.

The functional relationship among the devices, device drivers and functional drivers in the preferred embodiment is illustrated in Figure 2. The operating system 210 includes real mode (RM) device drivers 202 for the peripheral devices 120. The operating system 210 also includes protected mode (PM) device drivers 212 which control the same devices as the real mode device drivers 202. In the preferred embodiment, the operating system further includes real mode functional drivers 204 which supplement the real mode device drivers 202 and protected mode functional drivers 214 which supplement the protected mode device drivers 212. The functional drivers 204 may be part of the device drivers 202. In the preferred embodiment, the operating system 210 is composed of an embellished version of the Microsoft WINDOWS 3.1 operating system, sold by Microsoft Corporation of Redmond, Washington, provided on a platform of the Microsoft MS-DOS 5.0 operating system, also sold by Microsoft Corporation. The Microsoft MS-DOS operating system portion of the operating system 210 is loaded at boot time. The Microsoft WINDOWS operating system portion of the operating system 210 is loaded thereafter. Although the MS-DOS operating system portion of the operating system 210 is capable of executing only in real mode, the Microsoft

WINDOWS operating system portion of the operating system 210 is capable of executing in either real mode or protected mode.

In the first aspect of the invention, the preferred embodiment provides consistency among the drive unit number mapping for hard disks by real mode device drivers 202 and the protected mode device drivers 212. When a physical sector of a disk is accessed by either the real mode device drivers 202 or the protected mode device drivers 212, the real mode device drivers 202 and the protected mode device drivers 212 must know the drive unit number of the disk drive to access the sector of the disk. The operating system 210, includes as part of the MS-DOS operating system a Basic Input/Output System software module (BIOS). The BIOS contains a set of predefined functions that may be called by operating systems or applications to perform tasks. The functions are called by software interrupts. One such interrupt is the INT 13h ("h" designates hexadecimal) interrupt. Typically, a volume driver employs the INT 13h interrupt to request the performance of various operations on a disk, that is identified by a drive unit number. The drive unit number is loaded into a processor register at the time of the interrupt.

In order for the protected mode disk drivers 310 (Figure 3) to control access to the physical disks 320 in a fashion compatible with the real mode disk drivers 300, the protected mode disk drivers 310 must assign the same drive INT 13h unit numbers as the real mode disk drivers 300 assign to the physical disks 320. That is, for example, the drive unit number 0 assigned to a first hard disk for a real mode disk driver 300 must also be assigned by the protected mode disk driver 310 for the hard disk, as is shown in Figure 3. When the INT 13h drive unit number 0 is specified in a request to access a physical disk, via the real mode disk driver 300 or the protected mode disk driver 310, the same disk 320 is accessed by either disk driver which has assigned the drive unit number 0 to the disk driver 110 that it controls. Similarly, the similar parity of INT 13h unit number assignments must exist for the rest of the hard disks 320. This is not ensured by simply assigning the INT 13h drive unit numbers to the protected mode hard disk drivers 310 in the order that the protected mode hard disk drivers 310 are loaded because the protected mode hard disk drivers 310 do not necessarily load in the same order as the real mode hard disk drivers 300.

To ensure consistent drive unit numbers, as explained above, the preferred embodiment first creates a drive table 600, which will be described in greater detail with reference to Figure 6 below. The drive table 600 associates the drive unit number used by each real mode hard disk driver 300 with unique information stored on the physical hard disk accessed by that real mode hard disk driver 300. The protected mode hard disk drivers 310 then assign the drive unit numbers to the same physical hard disk 320 using the driver table. Each protected mode disk driver reads a selected portion of the physical disk to obtain the unique information and then extracts from the drive table the drive unit number that is associated with the unique information read from the physical hard disk. The extracted drive unit number is then assigned to the physical hard disk by the protected mode hard disk driver.

Figure 4 is a flow diagram of the process which creates the drive table described above, referred to herein as the Build Drive Table process. The Build Drive Table process can be implemented as software stored in the memory 102 and executed by the CPU 104 when the operating system 210 is loaded. In step 405, the Build Drive Table process initializes to 0 a disk drive counter n, and all checksum flags (described in more detail below) in the drive table, are also initialized to 0. In step 410, the Build Drive Table process initiates an INT 13h interrupt to the CPU 104 to read a first physical hard disk 320. The Build Drive Table process provides the hard disk drive counter value n as the drive unit number (initially 0), a value which specifies that a read function is to be performed, and the sector number of the sector in which the master boot record is stored on the disk. In step 415, the Build Drive Table process determines whether the master boot record read in step 410 is of a standard format used by the MS-DOS operating system 200. If so, a location is provided on the hard disk in which a unique signature (which will be explained below) can be stored. The Build Drive Table process determines that the master boot record format is standard when byte DAh of the master boot record contains a value of zero. If the Build Drive Table process determines in step 415 that the master boot record read in step 410 is of the standard format, then control proceeds to step 420.

In step 420, the Build Drive Table process determines whether the signature stored in a specific location of the master boot record has a non-zero value. Figure 5 illustrates the master boot record (MBR) at sector 0 of the physical hard disk read in step 410, and the signature provided therein. The signature is provided at consecutive bytes DCh and DDh of sector 0. If the Build Drive Table process determines in step 420 that the signature in the master boot record is a non-zero value, control proceeds to step 425. In step 425, the signature stored in bytes DCh and DDh is written into an entry in a drive table. Figure 6 illustrates the drive table into which the signature is written in step 425. In Figure 6, the drive table 600 contains a drive table entry 610 for each disk drive 110. The drive table entry 610 contains a drive unit number field 612, a signature field 614 into which the signature was written in step 425, and a checksum flag 616.

Control then proceeds to step 430. In step 430, the drive unit number n is written into the drive unit number field 612 of the same drive table entry 610 in which the signature was written into the signature field 614.

If the Build Drive Table process determines in step 420 that the signature in bytes DCh and DDh of the master boot record is 0, then control branches to step 435. In step 435, the Build Drive Table process determines whether the hard disk corresponding to the disk drive 110 is write-protected. If so, a new signature cannot be written onto the hard disk. If the Build Drive Table process determines in step 435 that the hard disk is not write-protected, then control proceeds to step 440. In step 440, the Build Drive Table process creates a new, unique signature and writes the new signature into bytes DCh and DDh of the master boot record.

If the Build Drive Table process determines in step 435 that the hard disk is write-protected, or if the Build Drive Table process determines in step 415 that the master boot record is not of the standard format, then control branches to step 445. In step 445 the Build Drive Table process computes a checksum of the contents of the first sector of the hard disk read in step 410. Control then proceeds to step 450 wherein the Build Drive Table process writes the computed checksum into the signature field 614 (Figure 6) of the drive table entry 610 provided for the disk drive 110. In step 455 (Figure 4), a checksum flag stored in the checksum flag field 616 of the drive table entry 610 for the hard disk 110 (and initialized to 0), is set to 1. Control then proceeds to step 430 in which, as explained above, the drive unit number n is written into the drive table 610 provided for the disk drive 110. Then, in step 465, the hard disk drive counter n is incremented. Control then proceeds to step 470, which determines whether all hard disk drives 110 have been processed. If not, the Build Drive Table process loops back to step 410. If so, the Build Drive Table process ends.

The drive table 600 created by the Build Drive Table process of Figure 4 is then used to determine the correct drive unit number to be used by each of the protected mode disk drivers 310. Figure 7 is a flow diagram of the process by which the protected mode disk drivers 310 assign the drive unit numbers to the physical hard disks, referred to herein as the Assign Drive Unit Number process. The Assign Drive Unit Number process can be implemented as software stored in the memory 102 and executed by the CPU 104 when the operating system 210 is loaded, during the loading of each protected mode disk driver 310 and after the Build Drive Table process has been performed.

In step 700 of the Assign Drive Unit Number process, a protected mode disk driver 310 is loaded. Control then proceeds to step 705. The process then determines whether the master boot record is standard or not (step 701). If the master boot record is not standard, a checksum of the master boot record is calculated (step 702). The resulting checksum is used as an index into the driver table to locate a driver entry table. In contrast, if the master boot record is standard, the Assign Drive Unit Number process reads the signature stored in bytes DCh and DDh of the master boot record of the physical hard disk (step 705). Control proceeds to step 710. In step 710, the Assign Drive Unit Number process finds the drive table entry 610 that has in the signature field 614 the signature read in step 705. Control then proceeds to step 715. In step 715, the drive unit number stored in the drive unit number field 612 of the drive table entry 610 found in step 710 is extracted, and the extracted drive unit number is assigned to the physical hard disk by the loaded protected mode disk driver 310. Control then proceeds to step 720, in which it is determined whether there are more protected mode disk drivers 310 to be loaded. If more protected mode disk drivers 310 are to be loaded, control loops back to step 700. Otherwise, the routine ends. As a result of the above process, the real mode disk drivers 300 and the protected mode disk drivers 310 which control the same hard disk drives 110 assign the same drive unit numbers to the same physical hard disks.

The second aspect of the invention will now be described. In the second aspect of the invention, the preferred embodiment provides consistency among the volume unit numbers for logical volumes that are used by the real mode device drivers 202 and the protected mode device drivers 212. A logical volume is all or a portion of a fixed storage medium such as a disk or tape. Each logical volume contains a self-sufficient file system containing at least one directory with zero or more files, and containing all the information required to locate these files and directories. The operating system 210 and application programs refer to a logical volume with a logical drive letter, such as "A:", "B:" when specifying a file or directory stored thereon. Although often a logical volume corresponds to a disk drive 110, a disk may contain more than one logical volume. When a logical volume is accessed by either the real mode device drivers 202 or the protected mode device drivers 212, the volume unit number (which corresponds to a logical drive letter) must be known in order to access the particular logical volume desired. The BIOS module, discussed above, provides an INT 25h interrupt handler through which an operating system or application program requests the performance of a logical volume READ function which reads a specific logical volume on a disk. The BIOS module also provides an INT 26h interrupt handler through which an operating system or application program may request a logical volume WRITE function which writes a

specific logical volume on the hard disk. When an INT 25h READ or INT 26h WRITE is requested, the volume unit number must be specified to identify the specific logical volume to be read or to be written.

Like the drive unit numbers discussed above, the volume unit numbers are assigned to the logical volumes by real mode device drivers 202 which control access to the logical volumes (real mode volume drivers) in an order designated by the operating system (e.g., the MS-DOS operating system, by Microsoft Corp.). When the operating system 210 is loaded thereafter, protected mode volume drivers are loaded which assign the volume unit numbers to the same logical volumes which the protected mode volume drivers control. A block diagram illustrating this relationship is shown in Figure 8. In order for the protected mode volume drivers 810 shown in Figure 8 to be compatible with the real mode volume drivers 800, the protected mode volume drivers 810 must assign the same volume unit numbers as the real mode volume drivers 800 assigned to the same logical volumes 830. Thus, as shown in Figure 8, volume unit number 0 is assigned to a first logical volume by the real mode volume driver 800 and by the protected mode volume driver 810 which access the first logical volume. Volume Unit Number 1 is assigned by the real mode volume driver 800 and by the protected mode volume driver 810 which access a next logical volume, and each subsequent logical volume is assigned a volume unit number of sequentially greater value, until the last volume unit number n is assigned.

To provide the consistent assignment of volume unit numbers described above, the preferred embodiment first creates a volume table 1100, which will be described in greater detail with reference to Figure 11 below. The volume table associates the volume unit number assigned by each real mode volume driver 800 with a unique serial number stored in the logical volume 830 accessed by that real mode volume driver 800. The protected mode volume drivers 810 assign the volume unit numbers to the same logical volume 830 using the volume table. Each protected mode volume driver reads the unique serial number from the logical volume 830 via the protected mode volume driver and extracts from the volume table the volume unit number associated with the unique serial number read from the logical volume.

Figure 9 is a flow diagram of the process which creates the volume table described above, referred to herein as the Build Volume Table process. The Build Volume Table process can be implemented as software stored in the memory 102 and executed by the CPU 104 when the operating system 210 is loaded. In step 900, the Build Volume Table process initializes to zero a logical volume counter m which will be described in more detail below. Control then proceeds to step 910. In step 910, the Build Volume Table process initiates an INT 25h interrupt. The logical volume counter m is specified as the volume unit number. The Build Volume Table process also specifies the logical sector of the logical volume storing the volume boot record as an interrupt parameter. The INT 25h interrupt causes a logical READ to be performed. The logical READ reads the designated logical sector having the specified volume boot record. This logical sector includes a unique serial number stored at a predetermined location on the volume boot record. The location of the volume boot record and serial number stored therein is obtained as shown in Figure 10. In Figure 10, the master boot record (MBR) of the disk on which the logical volume is provided contains a pointer to a partition boot record (PBR). The partition boot record contains a pointer to a first (VBR) which stores a serial number uniquely identifying a first logical volume. Where additional logical volumes are resident in the computer system, the partition boot record contains a pointer to a second partition boot record, as shown. The second partition boot record contains a pointer to the second volume boot record, which contains a different serial number that uniquely identifies the second volume. Additional logical volumes are represented in the same fashion.

Control then proceeds to step 920. In step 920, the Build Volume Table process writes the serial number obtained in the volume boot record into a volume table 1100, which is shown in Figure 11. The volume table 1100 contains a volume table entry 1110 for each logical volume resident on the computer system. Each volume table entry 1110 contains a volume unit number field 1112 and a serial number field 1114. The Build Volume Table process writes the serial number into the serial number field 1114 of the volume table entry 1110 provided for the logical volume controlled by the real mode volume driver 800 to which the volume unit number m is assigned. Control then proceeds to step 930. In step 930, the Build Volume Table process writes the volume unit number m into the volume unit number field 1112 of the volume table entry 1110 into which the serial number was written in step 920. Control then proceeds to step 940, in which the volume counter m is incremented. Then, in step 950, it is determined whether all of the logical volumes have been processed. If not, control loops to step 900. If so, the Build Volume Table process ends.

The volume unit numbers obtained are then assigned to the correct logical volume. A flow diagram of the process by which the volume unit numbers are assigned, called herein the Assign Volume Unit Number process, is shown in Figure 12. The Assign Volume Unit Number process shown in Figure 12 can be implemented as software that is stored in the memory 102 and executed by the CPU 104 when the

operating system 210 is loaded. In step 1200 of the Assign Volume Unit Number process, a protected mode volume driver 810 is loaded. Control then proceeds to step 1202. In step 1202, the assign protected mode volume number process reads the serial number (by the following the path from the master boot record to partition boot record to volume boot record) from the volume boot record of the logical volume. Control then proceeds to step 1204. In step 1204, the Assign Volume Unit Number process locates the volume table entry 1110 in the volume table 1100 which contains the serial number read in step 1202. In step 1206, the volume unit number stored in the volume unit number field 1112 of the volume table entry 1110 obtained in step 1204 is assigned to the logical volume by the loaded protected mode volume driver 810. In step 1208, the Assign Volume Unit Number process determines whether there are more volume boot records (VBR's) to process. If so, control loops to step 1200. Otherwise, the Assign Volume Unit Number process ends. As a result, the real mode volume drivers 800 and the protected mode volume drivers 810 use the same drive unit numbers for the volumes which they access.

The third aspect of the invention will now be described. In the third aspect of the invention, the preferred embodiment provides consistency among the adapter numbers for the adapters 108 (Figure 1). These adapter numbers are used by the real mode device drivers 202 and protect mode device drivers 212 to control the adapters 108 to access the peripheral devices 120 connected thereto. For example, the adapters 108 are SCSI adapters, and the MS-DOS operating system provides real mode SCSI adapter drivers. The SCSI adapter drivers include, for example, ASPI (Advanced SCSI Programming Interface) and CAM (Common Access Method) drivers. When the operating system 210 is loaded thereafter, protected mode adapter drivers are provided which control the same adapters 108 as the real mode adapter drivers.

A block diagram is shown in Figure 13 which illustrates the relationship among the adapter drivers and the adapters 108 described above. For the protected mode adapter drivers 1310 shown in Figure 13 to control the adapters 108 in a fashion compatible with the real mode adapter drivers 1300 that control the same adapters 108, the same adapter numbers must be assigned by the protected mode adapter drivers 1310 that the real mode adapter drivers 1300 assign to the same adapters 108. The adapter numbers are assigned by the real mode adapter drivers 1300 in an order. For example, when loaded by the MS-DOS operating system, the adapter numbers are assigned in the order that the real mode adapter drivers 1300 are loaded. The operating system 210, however, does not necessarily load the protected mode adapter drivers 1310 in the same order as the corresponding real mode adapter drivers 1300. Thus, it cannot be ensured that the same adapter numbers will be assigned to the real mode adapter drivers 1300 and the protected mode adapter drivers 1310 which control the same adapters 108.

Additionally, some application programs may request to use the real mode adapter drivers 1300, even when protected mode drivers are present. A still further complication is that an interface mapper 1320 may be provided which maps requests to access peripherals via a real mode adapter driver 1300 of one interface type (e.g., ASPI) to a real mode adapter driver 1300 of a different interface type (e.g., CAM). Thus, application program requests to access the real mode adapter drivers must be mapped to the protected mode adapter drivers 1310 which control the same adapters 108. Further, requests to access real mode adapter drivers 1300 which are mapped by an interface mapper 1320 to a destination real mode adapter driver 1300 must also be mapped to a protected mode adapter driver 1310 that corresponds to the destination real mode adapter driver 1300.

To provide consistent assignment of adapter numbers and mapping of requests to the correct protected mode adapter driver 1310, the preferred embodiment first creates for each adapter 108 a real mode data structure 1500, which will be described in greater detail with reference to Figure 15 below. The real mode data structure associates the adapter number assigned by a real mode adapter driver 1300 to the adapter 108 which the real mode adapter driver controls with peripheral information obtained from each peripheral device 120 connected to the same adapter 108. When an interface mapper 1320 is provided, the real mode data structure also associates the adapter number and peripheral information with an interface type. The interface type defines the type of interface of the destination real mode adapter driver 1300 to which requests to the real mode adapter driver 1300 are mapped by the interface mapper 1320.

When the protected mode adapter drivers 1310 are loaded thereafter, a data control block 1800 is created for each peripheral device 120 connected to an adapter 108. The data control block 1800 will be described in greater detail with reference to Figure 18 below. The data control block contains peripheral information obtained from each peripheral 120 via the adapter 108 controlled by the protected mode adapter driver 1310. The peripheral information in each data control block is then compared to the peripheral information stored in the real mode data structures 1500. When the peripheral information is the same, the adapter number is extracted from the real mode data structure 1500. The extracted adapter number is assigned to the adapter 108 connected to the peripheral 120 for which the data control block is provided by the protected mode adapter driver 1310 which controls that adapter 108.

In the case where an interface mapper 1320 is provided, the peripheral information in more than one real mode data structure may match the peripheral information in the data control block 1800. In such a case, the adapter number which corresponds to the destination real mode adapter driver 1300 is assigned to the adapter 108 connected to the peripheral 120 corresponding to the data control block by the protected mode adapter driver which controls that adapter 108. This adapter number is obtained from the real mode data structure that associates the adapter number with an interface type (i.e., the interface type of the destination real mode adapter driver 1300).

A flow diagram of the process which creates the real mode data structures described above, referred to herein as the Build Real Mode Data Structures (RMDs) process, is shown in Figure 14. The Build RMDs process can be implemented as software stored in the memory 102 and executed by the CPU 104. In step 1400, the Build RMDs process initializes the interface type, adapter counter, peripheral counter, and real mode data structure (all of which will be described in more detail below). In step 1402, the Build RMDs process provides an SCSI inquiry instruction via the real mode adapter driver 1300 to which the adapter number indicated by the adapter counter (initially 0) is assigned. The SCSI inquiry instruction obtains peripheral information from the peripheral device 120 indicated by the peripheral unit counter (initially 0 for each adapter). Then, in step 1404, the Build RMDs process stores the peripheral information and the adapter number together in a unit specifier corresponding to the peripheral 120 and associated with the real mode data structure corresponding to the adapter 108.

The real mode data structure and unit specifier are shown in detail in Figure 15. Each RMD 1500 contains a next RMD pointer 1502 and a unit pointer 1504. The next RMD pointer 1502 points to a next RMD corresponding to a next real mode adapter driver 1300. The next real mode adapter driver 1300 is the adapter driver that was loaded next after the real mode adapter driver 1300 to which the RMD 1500 corresponds. The unit pointer 1504 points to a first unit specifier 1510 having a peripheral data field 1512 and a unit pointer 1514. The unit pointer 1514 points to a next unit specifier 1510 corresponding to a next peripheral device 120 connected to the adapter 108 that corresponds to the RMD 1500. The specific contents of the peripheral data field 1512 are shown in Figure 16. The peripheral data field 1512 contains peripheral information 1600 comprising a target ID 1602, a logical unit number 1604, and a checksum 1606 obtained from the peripheral device 120 to which the unit specifier 1510 corresponds. The peripheral data field 1512 further includes an interface type 1610 and an adapter number 1620 which corresponds to the adapter 108 to which the RMD 1500 corresponds.

After the peripheral information is stored in step 1404 of the Build RMDs process, control proceeds to step 1406. In step 1406, the Build RMDs process determines whether a real mode adapter driver 1300 has been called in performing the SCSI inquiry instruction which differs from the interface type initially specified. For example, the interface type is initially set to ASPI, such that the SCSI inquiry instruction is first provided via all real mode adapter drivers 1300 which are ASPI drivers. In such a case, the Build RMDs process initially determines in step 1406 whether a real mode adapter driver 1300 having an interface type other than ASPI has been called. A real mode adapter driver 1300 having a different interface type is called whenever an interface mapper 1320 is provided which maps requests to the real mode adapter driver 1300 to a different, destination real mode adapter driver 1300. If, in step 1406, the Build RMDs process determines that a different interface type has been called, then control branches to step 1408. In step 1408, the Build RMDs process stores the interface type of the destination real mode adapter driver 1300 as the interface type 1610 in the peripheral data field 1512 of the RMD 1500, replacing the zero values initially stored in the peripheral data field 1512. The RMD 1500 into which the interface type is stored corresponds to the real mode adapter driver 1300 to which the adapter number represented by the adapter counter is assigned.

If, in step 1406, the Build RMDs process determines that a different interface type is not called, then control proceeds to step 1410. Control also proceeds to 1410 after step 1408 is performed. In step 1410, the peripheral counter is incremented and the next unit specifier 1510 is obtained. Control proceeds to step 1412. In step 1412, the Build RMDs process determines whether all of the peripheral devices 120 connected to the adapter 108 have been processed. Is so, control loops back to step 1402. If not, control branches to step 1414, in which the adapter counter is incremented.

Control then proceeds to step 1416 wherein the peripheral counter is reset to 0 and the next RMD is obtained. In step 1418, the Build RMDs process determines whether all of the adapters 108 have been processed. If so, the Build RMDs process ends. If not, control branches to step 1420, in which the Build RMDs routine determines whether the interface type of the last real mode adapter driver 1300 is ASPI. If so, then in step 1422 the Build RMDs routine determines whether all of the ASPI drivers have been processed. If not, control loops to step 1402. If so, control proceeds to step 1424, in which the interface type is set to CAM. Control then loops to step 1402. If, in step 1420, the Build RMDs process determines that the

interface type is not ASPI, then control branches to step 1426, in which the Build RMDs process determines whether the interface type of the last real mode adapter driver 1300 is CAM. If so, control proceeds to step 1426, wherein the Build RMDs process determines whether all CAM drivers have been processed. If not, control loops to step 1402. If so, control proceeds to step 1430 wherein the interface type is set to INT 4B. Control then loops to step 1402.

The process which creates the device control blocks, referred to herein as the Build Device Control Blocks (DCBs) process, is shown in Figure 17. The Build DCBs process can be implemented as software stored in the memory 102 and executed by the CPU 104 when the operating system 210 is loaded. In step 1700, the Build DCBs process loads a protected mode adapter driver 1310. Control then proceeds to step 1705. In step 1705, the Build DCBs process scans the peripheral information via the loaded protected mode driver 1310 from a peripheral device 120 connected to the adapter 108 which is controlled by the loaded protected mode adapter driver 1310. Control then proceeds to step 1710. In step 1710, the Build DCBs process stores the peripheral information scanned in step 1705 into a device control block (DCB) corresponding to the loaded protected mode adapter driver 1310. The device control block (DCB) into which the peripheral information is stored is shown in Figure 18. As shown in Figure 18, the device control block 1800 contains a target ID 1802 which identifies the peripheral device, a logical unit number 1804, and a checksum 1806 based on the peripheral information scanned from the peripheral device 120 connected to the adapter 108 controlled by the loaded protected mode adapter driver 1310.

Control then proceeds to step 1715. In step 1715, the Build DCBs process determines whether more peripheral devices 120 are connected to the adapter 108 which is controlled by the loaded protected mode adapter driver 1310. If so, control loops to step 1700. Otherwise, control proceeds to step 1720, in which the Build DCBs process determines whether more protected mode adapter drivers are to be loaded. If the Build DCBs routine determines in step 1720 that more protected mode adapter drivers 1310 are to be loaded, then control loops to step 1700. Otherwise, the Build DCBs process ends.

A flow diagram of the process which assigns the adapter numbers to the protected mode adapter drivers 1310, referred to herein as the Assign Adapter Numbers process, is shown in Figure 19. The Assign Adapter Numbers process may be implemented as software stored in the memory 102 and executed by the CPU 104. In step 1900, the Assign Adapter Numbers process initializes the DCBs 1800, the RMDs 1500 and the unit specifiers 1510, which will be explained. In step 1902, a "matches" counter is initially set to 0, which will also be explained. In step 1904, the peripheral information stored in a unit specifier 1510 of an RMD 1500 is compared to the peripheral information stored in a DCB 1800. Control then proceeds to step 1906. In step 1906, the Assign Adapter Numbers process determines whether the peripheral information in the unit specifier 1510 is the same as the peripheral information in the DCB 1800.

If, in step 1906, it is determined that the peripheral information matches, control proceeds to step 1908. In step 1908, the matches counter is incremented. Control then proceeds to step 1910, in which a destination flag indexed by the value of the matches counter is initially set to be False. Control then proceeds to step 1912. In step 1912, the adapter number stored in the unit specifier 1510 is assigned to a "Driver" variable indexed by the value of the matches counter. The Driver variable tentatively contains the adapter number of the protected mode adapter driver 1310 corresponding to the DCB 1800. Control then proceeds to step 1914. In step 1914, it is determined whether an interface type 1610 (a non-zero value) is stored in the peripheral data field 1512 of the unit specifier 1510. The interface type 1610 is initially a zero value, and is set to an interface type only when stored in step 1408 of the Build RMDs process in Figure 14. Step 1408 is only performed when an interface mapper 1320 has been provided which maps a request to a real mode adapter driver 1300 to a different, destination real mode adapter driver 1300. If, in step 1914, it is determined that a non-zero value is stored as the interface type 1610 in the peripheral data field 1512 of the unit specifier 1510, then control proceeds to step 1916. In step 1916, the destination flag indexed by the value of the matches counter is set to True.

Control then proceeds to step 1922, in which the Assigned Adapter Number process determines whether more unit specifiers 1510 correspond to the RMD 1500. If so, control proceeds to step 1924, in which the next unit specifier 1510 is obtained, and control then loops to step 1902. Otherwise, control branches to step 1926, in which it is determined whether more RMDs 1500 are provided. If so, the next RMD 1500 is obtained and control loops to step 1902. Otherwise, control branches to step 1930. In step 1930, the adapter number of the matching RMD is assigned to the adapter 108 to the protected mode adapter driver 1310 corresponding to the DCB which matches that RMD. When more than one RMD matched the DCB, the adapter number stored in the RMD that is associated with an interface type (that of the destination real mode adapter driver) is assigned by the protected mode adapter driver 1310. This assignment can be illustrated by the following pseudocode:

```
if matches = 1
     then adapter number = Driver (matches)

if matches > 1
     then for n = 1 to matches
          if destination (matches) = True
               then adapter number = Driver (matches).
```

Control then proceeds to step 1932, wherein it is determined whether more DCBs are to be processed. If so, control proceeds to step 1934, in which the next DCB is obtained, and control then loops to step 1902. If not, the routine ends.

In a fourth aspect of the invention, the preferred embodiment provides protected mode accommodation of real mode functional drivers 204 which have been provided. In the fourth aspect of the invention, the preferred embodiment first detects the use of such real mode functional drivers 204. The preferred embodiment determines whether the functionality of the detected real mode functional drivers 204 is provided by a resident protected mode functional driver. If so, requests to the real mode functional drivers are mapped to the protected mode functional drivers 214. If not, the preferred embodiment adapts the real mode functional drivers 204 to work with the protected mode device drivers 212 instead of the real mode device drivers 202.

The process which accommodates the real mode functional drivers, referred to herein as the Accommodate Real Mode (RM) Functional Drivers process, is shown in Figure 20. The Accommodate Real Mode Functional Drivers process may be implemented as software stored in the memory 102 and executed by the CPU 104. In step 2000 of the Accommodate Real Mode Functional Drivers process, the Accommodate Real Mode Functional Drivers process performs a Detect Real Mode Functional Driver process which detects a real mode functional driver. The Detect Real Mode Functional Driver process is shown in Figure 21. In step 2100 of the Detect Real Mode Functional Driver process the Boolean value "detected" is initially set to False. Control then proceeds to step 2105. In step 2105, the Detect Real Mode Functional Driver process obtains current driver information from a disk parameter block provided for a real mode logical driver.

The disk parameter block is shown in Figure 22. As shown in Figure 22, the data parameter block 2200 contains current driver information 2202 and a pointer 2204 to a first driver to execute. Initially, the pointer 2204 in the data parameter block 2200 points to a real mode device driver 2210 which controls a device 2220 also controlled by a protected mode device driver 2230. Where a real mode functional driver 2240 has been provided to supplement the real mode device driver 2210, however, the calls to be real mode functional driver 2240 are hooked such that the pointer 2204 points to the real mode functional driver 2240. In such a case, the current driver information 2202 describes the real mode functional driver 2240 instead of the real mode device driver 2210 originally described thereby. It should be appreciated that the functional drivers may be part of the real mode drivers rather than separate drivers.

Control then proceeds to step 2110. In step 2110, the Detect Real Mode Functional Driver process obtains an original driver structure from the IO.SYS module. The IO.SYS software module is a well-known module provided by the hardware manufacturer of the computer system to start up the MS-DOS operating system 200. The original driver structure is shown in Figure 23. The original driver structure contains a real mode driver name, a number of units controlled, and a real mode driver header address. Control then proceeds to step 2115 in which the real mode driver name, a number of units controlled and the real mode driver header address in the original driver structure 2300 are compared to the current driver information corresponding to the same device 2220. Where a real mode functional driver 2240 has been provided, the information in the original driver structure 2300 will not match the current driver information 2202 in the data parameter block 2200. Thus, when in step 2115 it is determined that the current driver information does not match, control proceeds to step 2120, wherein the "detected" flag is set to True. Otherwise, the detected flag remains False. The process then returns to continue performing the Accommodate Real Mode Functional Drivers process shown in Figure 20.

After the Detect Real Mode Functional Driver process has been performed in step 2000 of the Accommodate Real Mode Functional Drivers process, control proceeds to step 2010. In step 2010, it is

determined whether the detected flag was set to be True by the Detect Real Mode Functional Driver process. If so, control proceeds to step 2015. In step 2015, it is determined whether the real mode functional driver name is found in a "safe driver" list. The safe driver list is illustrated in Figure 24. In Figure 24, the safe driver list 2400 contains a list of real mode functional driver names 2402. If, in step 2015, the real mode functional driver name is found on the safe driver list, then control proceeds to step 2025. In step 2025, the Accommodate Real Mode Functional Drivers process maps real mode functional driver requests to the protected mode driver identified in the safe driver list.

If the real mode functional driver name is not found in the safe driver list in step 2015, then control branches to step 2030, in which the Adapt Real Mode Functional Drivers process is performed. Control then proceeds to step 2035, wherein the Accommodate Real Mode Functional Drivers process determines whether more real mode logical drivers are provided. If so, control proceeds to step 2040 in which the next real mode logical driver is obtained, and control then loops to step 2000. If not, the Accommodate Real Mode Functional Drivers process ends.

Figure 25 shows several of the major functional steps performed by the Adapt Real Mode Functional Driver process. This process is performed by executing software that is stored in memory 102 and executed by the CPU 104. This process is invoked when the protected mode driver is not on the safe driver list and, thus, the Real Mode Functional Driver must be relied upon to provide the desired functionality. Hence, as shown in Figure 25, the logical requests to the protected mode driver are routed via a real mode mapper to a real mode functional driver (step 2500). This request is then passed down the real mode driver chain until the request reaches the last driver in the chain (step 2502). API calls by the real mode driver are hooked into protected mode (step 2504). Thus, ASPI, CAM or INT 13h API calls are hooked into protected mode. If there are no API calls, there is no hook into protected mode.

Although the present invention has been described with reference to one or more specific embodiments, it should be appreciated that various changes can be made by one of ordinary skill in the art without departing from the spirit of the invention. The scope of the invention is Properly defined by the Claims.

Claims

1. A method, performed by a computer connected to at least one device and capable of operating in a real mode and a protected mode, of a protected mode device driver assigning a same reference value to a device accessed by the protected mode device driver as a real mode device driver which accesses the same device assigns to the same device, the method comprising the steps of:
   (a) the real mode device driver assigning a unique reference value to the device accessed by the real mode device driver;
   (b) the real mode device driver accessing the device to which the reference value was assigned in step (a), to read device information which uniquely identifies the device;
   (c) storing the reference value assigned to the device by the real mode device driver in step (a) in a memory location associated with the device information read from the device in step (b);
   (d) the protected mode device driver accessing the device to read the device information;
   (e) obtaining the reference value stored in step (c) in the memory location associated with the device information accessed by the protected mode device driver in step (d); and
   (f) the protected mode device driver assigning the reference value obtained in step (e) to the device accessed by protected mode device driver in step (d).

2. The method of claim 1 wherein step (c) comprises storing the reference value and the device information in a same entry in a table data structure having an entry for each device connected to the computer.

3. A method, performed by a computer connected to at least one disk drive and capable of operating in a real mode and a protected mode, of a protected mode disk driver assigning a same drive unit number to a device accessed by the protected mode disk driver as a real mode disk driver which accesses the same disk drive assigns to the same disk drive, the method comprising the steps of:
   (a) the real mode disk driver assigning a unique drive unit number to the disk drive accessed by the real mode disk driver;
   (b) the real mode disk driver accessing the disk drive to which the drive unit number was assigned in step (a), to read disk information which uniquely identifies the disk residing on the disk drive;
   (c) storing the drive unit number identifying the disk in a memory location associated with the disk information read from the disk in step (b);

(d) the protected mode disk driver accessing the disk drive to read the disk information from the disk residing on the disk drive;
(e) obtaining the drive unit number stored in step (c) in the memory location associated with the disk information read by the protected mode disk driver in step (d); and
(f) the protected mode disk driver assigning the drive unit number obtained in step (e) to the disk drive accessed by the protected mode disk driver in step (d).

4. The method of claim 3 wherein
step (b) comprises reading a unique value stored on a predetermined location on the disk as the disk information, and wherein
step (c) comprises storing the drive unit number with the unique value in a same entry in a table data structure having an entry for each disk drive connected to the computer.

5. The method of claim 4, further comprising the steps of
(g) determining whether the disk stores a unique value in the predetermined location, and
(h) writing the unique value into the predetermined location if it is determined in step (g) that the disk does not store a unique value in the predetermined location.

6. The method of claim 3 wherein step (c) comprises storing the drive unit number in a memory location associated with a checksum of the disk information.

7. The method of claim 3, further comprising the step of (g) determining whether the disk has a predetermined format, and wherein
step (c) comprises the steps of
(i) storing the drive unit number in a memory located associated with a unique value read from a predetermined location on the disk if it is determined in step (g) that the disk has a predetermined format of data stored in a particular location, and
(ii) storing the drive unit number in a memory location associated with a checksum of the disk information if it is determined in step (g) that the disk does not have the predetermined format of data stored in the particular location.

8. The method of claim 7 wherein step (c) further comprises
(iii) storing the drive unit number in a memory location associated with a flag indicating whether the disk has a predetermined format, and wherein
step (e) comprises the steps of
(i) reading the flag,
(ii) obtaining the drive unit number stored in the memory location associated with the unique value if the flag indicates that the disk has the predetermined format, and
(iii) obtaining the drive unit number stored in the memory location associated with the checksum if the flag indicates that the disk does not have the predetermined format.

9. The method of claim 3 wherein the disk includes a master boot record used at boot time and wherein the disk information is stored on the master boot record of the disk.

10. A method, performed by a computer capable of operating in a real mode and a protected mode and connected to at least one disk drive having a disk containing at least one logical volume, of a protected mode device driver assigning a same reference value to a volume accessed by the protected mode volume driver as a real mode volume driver which accesses the same logical volume assigns to the same logical volume, the method comprising the steps of:
(a) the real mode volume driver assigning a unique volume unit number to the volume accessed by the real mode volume driver;
(b) the real mode volume driver accessing the logical volume to which the volume unit number was assigned in step (a), to read volume information which uniquely identifies the volume;
(c) storing the volume unit number assigned to the logical volume by the real mode volume driver in step (a) in a memory location associated with the volume information read from the disk in step (b);
(d) the protected mode volume driver accessing the volume to read the volume information;
(e) obtaining the volume unit number stored in step (c) in the memory location associated with the volume information read by the protected mode volume driver in step (d); and

(f) the protected mode volume driver assigning the volume unit number obtained in step (e) to the disk accessed by the protected mode volume driver in step (d).

11. The method of claim 10 wherein

step (b) comprises reading a volume serial number stored on a predetermined location on the logical volume as the volume information, and wherein

step (c) comprises storing the volume unit number in a same entry in a table data structure having an entry for each volume on the disk on each disk drive connected to the computer with the volume serial number.

12. The method of claim 10 wherein the volume includes a volume boot record and wherein the volume information is stored on the volume boot record.

13. A method, performed by a computer capable of operating in a real mode and a protected mode and connected to at least one adapter which is connected to at least one peripheral device, of a protected mode adapter driver assigning a same reference value to an adapter controlled by the protected mode adapter driver as a real mode adapter driver controlling a same adapter to access the one or more peripheral devices connected to the adapter, the method comprising the steps of:

(a) the real mode adapter driver assigning a unique adapter number to the real mode device driver;

(b) the real mode adapter driver scanning, from a peripheral device via an adapter to which the adapter number was assigned in step (a), peripheral device information which uniquely identifies the peripheral device;

(c) storing the adapter number assigned to the adapter in a memory location associated with the peripheral device information read from the peripheral device in step (b);

(d) the protected mode adapter driver controlling the adapter to access the peripheral device to scan the peripheral device information;

(e) obtaining the adapter number stored in step (c) in the memory location associated with the peripheral device information scanned by the protected mode adapter driver in step (d); and

(f) the protected mode adapter driver assigning the adapter number obtained in step (e) to the adapter controlled by the protected mode adapter driver in step (d).

14. The method of claim 13 wherein

step (b) comprises scanning a target ID which identifies the peripheral device as the peripheral device information, and wherein

step (c) comprises storing the adapter number with the target ID together in a same data structure.

15. The method of claim 13 wherein

step (b) comprises scanning as the peripheral device information a logical unit number, stored on a predetermined location on the disk, and wherein

step (c) comprises storing the adapter number with the logical unit number together in a same data structure.

16. The method of claim 13 wherein step (c) comprises storing the adapter number with a checksum of the peripheral device information together in a same data structure.

17. The method of claim 13 wherein step (c) comprises storing the adapter number and peripheral device information in a memory location associated with a driver type of a second real mode peripheral driver if the real mode peripheral driver is a first real mode peripheral driver for which application program requests are mapped to the second real mode peripheral driver.

18. The method of claim 13 wherein step (c) comprises

(i) providing one or more real mode adapter data structures having a pointer to a next adapter data structure and a pointer to a linked list of one or more real mode peripheral data structures, and

storing the peripheral device information for each peripheral device read via each adapter identified by the adapter number in a real mode peripheral data structure corresponding to the peripheral device and pointed to by a real mode adapter data structure corresponding to the adapter to which the peripheral device is connected.

19. The method of claim 18 wherein

step (e) comprises the steps of

(i) comparing the peripheral device information in each protected mode peripheral data structure to the peripheral device information in each real mode peripheral data structure to determine whether the peripheral device information matches, and

(ii) extracting the adapter number from the real mode peripheral data structure having the peripheral device information that matches the peripheral device information in each protected mode peripheral data structure, and wherein

step (f) comprises the protected mode adapter driver controlling the adapter connected to the peripheral device corresponding to the protected mode data structure assigning the adapter number extracted in step (e) to the adapter connected to the peripheral device corresponding to the protected mode data structure.

20. The method of claim 17 wherein step (c) comprises storing the peripheral device information in a memory location associated with the driver type of the second real mode peripheral driver via which the peripheral device information was read in step (b) when the first peripheral driver maps the read performed in step (b) to the second real mode peripheral driver, and wherein

step (f) comprises

(i) determining whether two real mode adapter drivers have been determined in step (e) to have the same peripheral device information as a protected mode adapter driver, and

(ii) the protected mode adapter driver assigning the adapter number to the protected mode peripheral driver having the driver type indicated by one of the real mode peripheral data structures if it is determined in step (i) that two real mode adapter drivers have the same peripheral device information.

21. A method of determine whether to execute a protected mode functional driver instead of a real mode functional driver, the method performed by a computer and comprising the steps of:

(a) designating one or more protected mode functional drivers each as executable instead of a corresponding real mode functional driver.

(b) detecting the real mode functional driver in the computer;

(c) determining whether one of the protected mode functional drivers have been designated as executable instead of the detected real mode functional driver in step (a);

(d) executing the protected mode functional driver instead of the detected real mode functional driver when it is determined in step (b) that the protected mode functional driver has been designated as executable instead of the real mode functional driver.

22. The method of claim 21 wherein step (b) comprises the steps of

(i) storing original real mode device driver information identifying a real mode device driver originally designated to access the real mode device driver when the real mode device driver was loaded,

(ii) storing current real mode device driver information identifying a real mode device driver which concurrently accesses the device,

(iii) comparing the original real mode device driver information with the current real mode device driver information, and

(iv) determining, when the original real mode device driver information is not the same as the current real mode device driver information, that a real mode functional driver is executed when the device is accessed.

23. The method of claim 21 wherein

step (a) comprises storing a name of the protected mode functional driver in a list of names of one or more protected mode functional drivers, each of which provide a function of a corresponding real mode driver having a name stored with the name of the protected mode functional driver that provides the function of the real mode functional driver, and

step (c) comprises determining whether the name of the protected mode functional driver is stored with the name of the detected real mode driver in the list.

24. The method of claim 21, further comprising the step of

(e) executing, if it is determined that a protected mode functional driver has not been designated as executable instead of the detected real mode functional driver, the detected real mode functional driver

while mapping real mode device driver requests for the detected real mode functional driver to access the device to a protected mode device driver which accesses the device in protected mode.

25. The method of claim 24 wherein step (e) comprises the steps of

(i) determining whether the detected real mode functional driver requests access to the device via a real mode adapter driver, and

(ii) mapping, when it is determined in step (i) that the detected real mode functional driver requests access to the device via the real mode adapter driver, the request to a protected mode adapter driver.

26. The method of claim 24 wherein step (e) comprises the steps of

(i) determining whether the detected real mode functional driver requests access to the device via a real mode physical disk driver, and

(ii) mapping, when it is determined in step (i) that the detected real mode functional driver requests access to the device via the real mode physical disk driver, the request to a protected mode physical disk driver.

27. A computer system having a computer with a processor and a memory and connected to one or more devices, the computer system comprising:

a real mode device driver stored in the memory and executed by the processor, and assigning a reference value to the device that the real mode device driver accesses;

a protected mode device driver stored in the memory and executed by the processor; and

means for the protected mode device driver assigning a same reference value to the device the protected mode device driver accesses as the real mode device driver assigns to the same device.

28. The computer system of claim 28 wherein

the device comprises a disk drive on which a physical disk resides, the real mode device driver is a real mode disk driver which controls the disk drive to access the physical disk in real mode and the protected mode device driver is a protected mode disk driver which control the disk drive to access the physical disk in protected mode, and wherein

the means for the protected mode device driver assigning the same reference value comprises the protected mode disk driver assigning a same drive unit number to the disk drive as the real mode disk driver which accesses the same physical disk.

29. The computer system of claim 28 wherein the means for the protected mode device driver assigning the same reference value comprises

a drive table having an entry for each real mode disk driver, the entry containing a unique value stored on the physical disk accessed by the real mode disk driver and containing a drive unit number which has been previously assigned by the real mode disk driver, and

means for the protected mode disk driver assigning the reference value contained in the entry to the physical disk which stores the unique value also contained in the entry.

30. The computer system of claim 27 wherein

the device comprises a disk drive on which a logical volume resides, the real mode device driver is a real mode volume driver which controls the disk drive to access the logical volume in real mode and the protected mode device driver is a protected mode volume driver which controls the disk drive to access the logical volume in protected mode, and wherein

the means for the protected mode device driver assigning the same reference value comprises the protected mode disk driver assigning a same volume unit number to the volume as the real mode volume driver which accesses the same logical volume.

31. The computer system of claim 30 wherein the means for the protected mode device driver assigning the same reference value comprises

a drive table having an entry for each real mode volume driver, the entry containing a unique value stored on the logical volume accessed by the real mode volume driver and containing a volume unit number which has been previously assigned by the real mode volume driver, and

means for the protected mode volume driver assigning the reference value contained in the entry to the logical volume which stores the unique value also contained in the entry.

32. The computer system of claim 27 wherein

the device comprises an adapter to which one or more peripheral devices are attached, the real mode device driver is a real mode adapter driver which controls the adapter to access the peripheral devices in real mode and the protected mode device driver is a protected mode adapter driver which controls the adapters to access the peripheral devices in protected mode, and wherein

the means for the protected mode adapter driver assigning the same reference value comprises the protected mode adapter driver assigning a same adapter number to the adapter as the real mode adapter driver which controls the same adapter to access the same peripherals.

33. The computer system of claim 32 wherein the means for the protected mode adapter driver assigning the same adapter number comprises

a real mode data structure provided for each real mode adapter driver, the real mode data structure associating, for each peripheral attached to the adapter controlled by the real mode adapter driver for which the real mode data structure is provided, unique peripheral information scanned from the peripheral device connected to the adapter controlled by the real mode adapter driver with an adapter number which has been previously assigned by the real mode adapter driver, and

means for the protected mode adapter driver assigning the adapter number associated with the unique peripheral information to the adapter that accesses the peripheral from which the unique peripheral information is scanned.

34. A computer system having a computer with a processor and a memory and connected to one or more devices, the computer system comprising:

a real mode device driver stored in the memory and executed by the processor to control access to one of the devices;

a real mode functional driver stored in the memory;

a protected mode device driver stored in the memory and executed by the processor to control access to one of the devices;

means for determining whether the computer system further includes a protected mode functional driver which has been designated as executable instead of the real mode functional driver; and

means for executing, when a protected mode functional driver has been designated as executable instead of the real mode functional driver, the determined protected mode functional driver when execution of the real mode functional driver is requested.

35. The computer system of claim 34, further comprising means for executing, when a protected mode functional driver has not been designated as executable instead of the real mode functional driver, the real mode functional driver while mapping requests, by the real mode functional driver to access the device via a real mode device driver to a protected mode device driver which accesses the same device.

36. The method of claim 34 wherein the means for determining whether the protected mode operating system further includes a protected mode functional driver which has been designated as executable instead of the real mode functional driver comprises a data structure which associates the real mode functional driver with a protected mode functional driver that provides a same function.

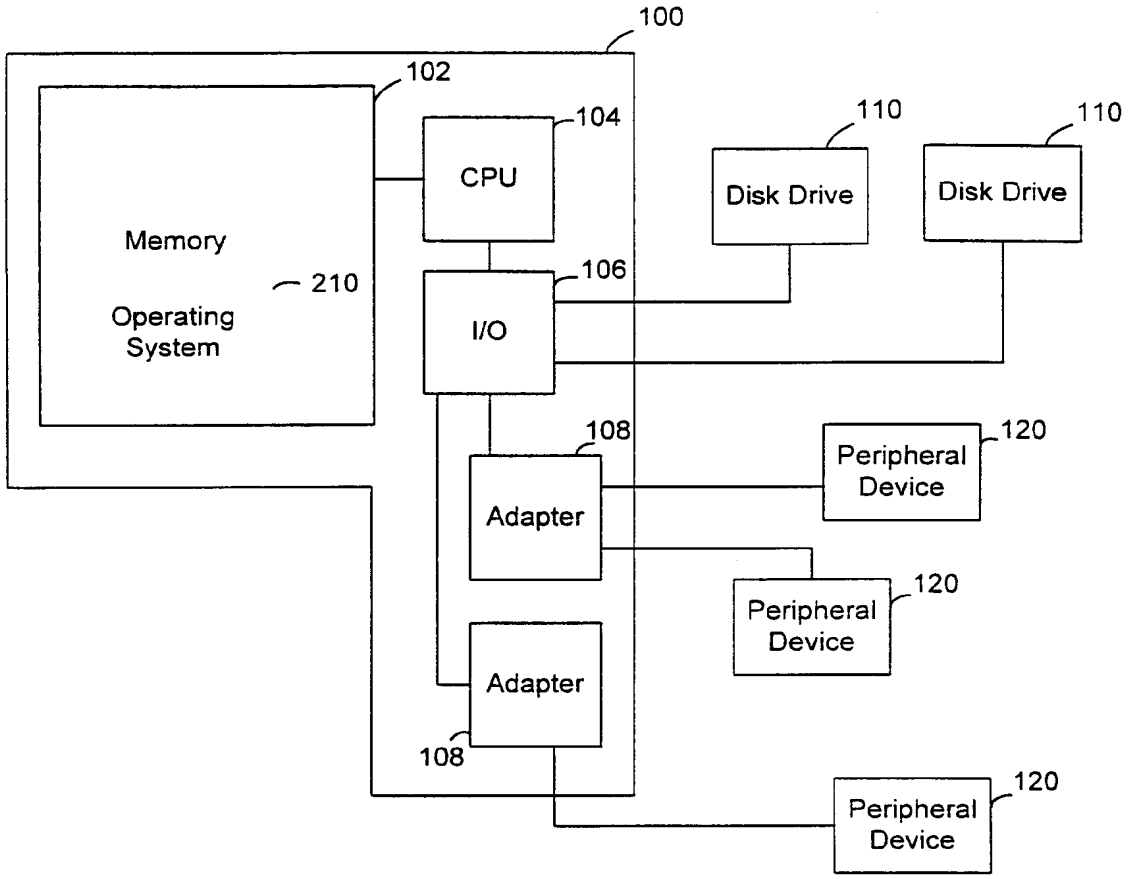

100
102
104
CPU
110
Disk Drive
110
Disk Drive
Memory
210
Operating System
106
I/O
108
Adapter
120
Peripheral Device
120
Peripheral Device
Adapter
108
120
Peripheral Device

FIG. 1

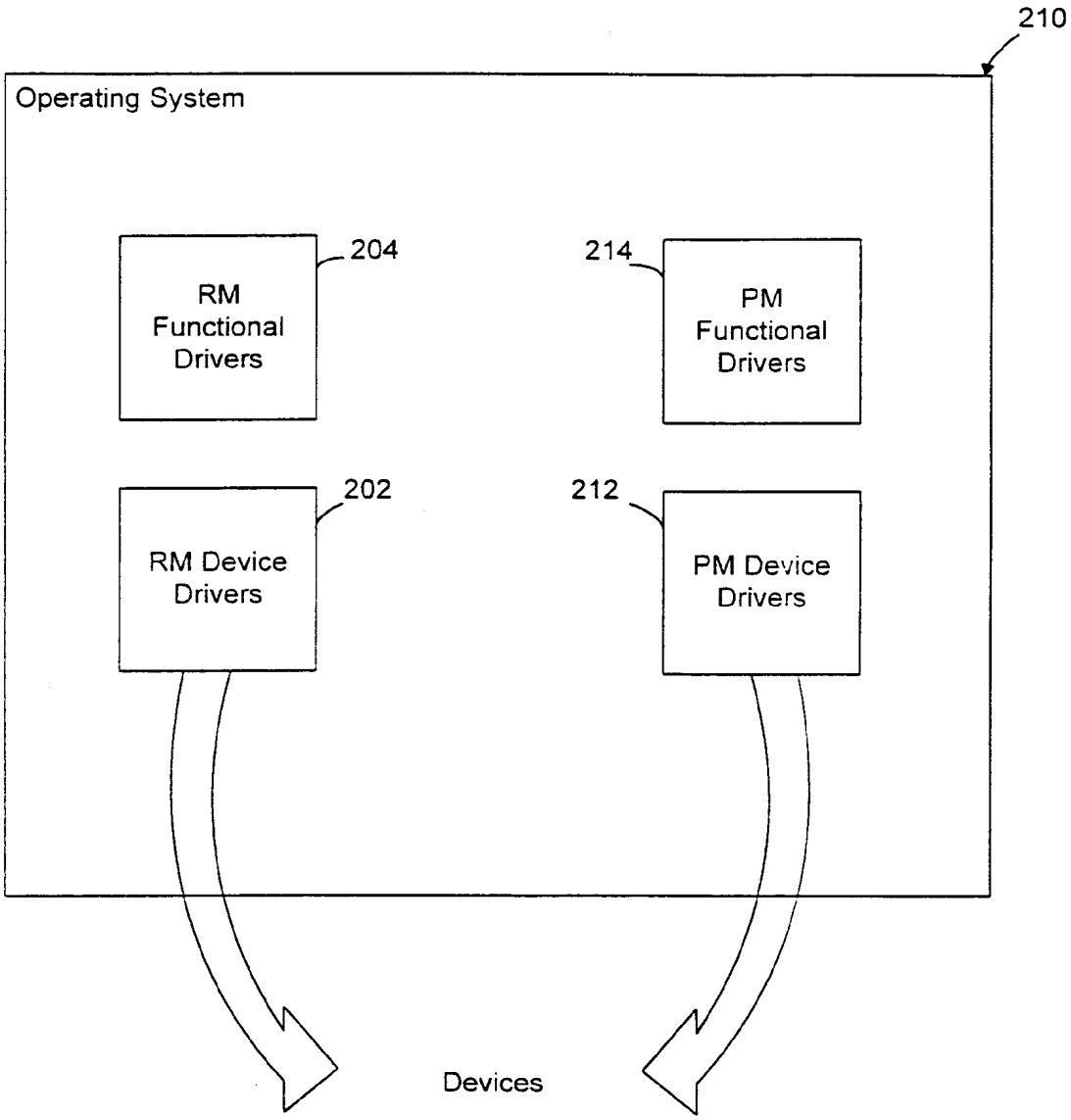

210
Operating System
204
RM
Functional
Drivers
214
PM
Functional
Drivers
202
RM Device
Drivers
212
PM Device
Drivers
Devices

FIG. 2

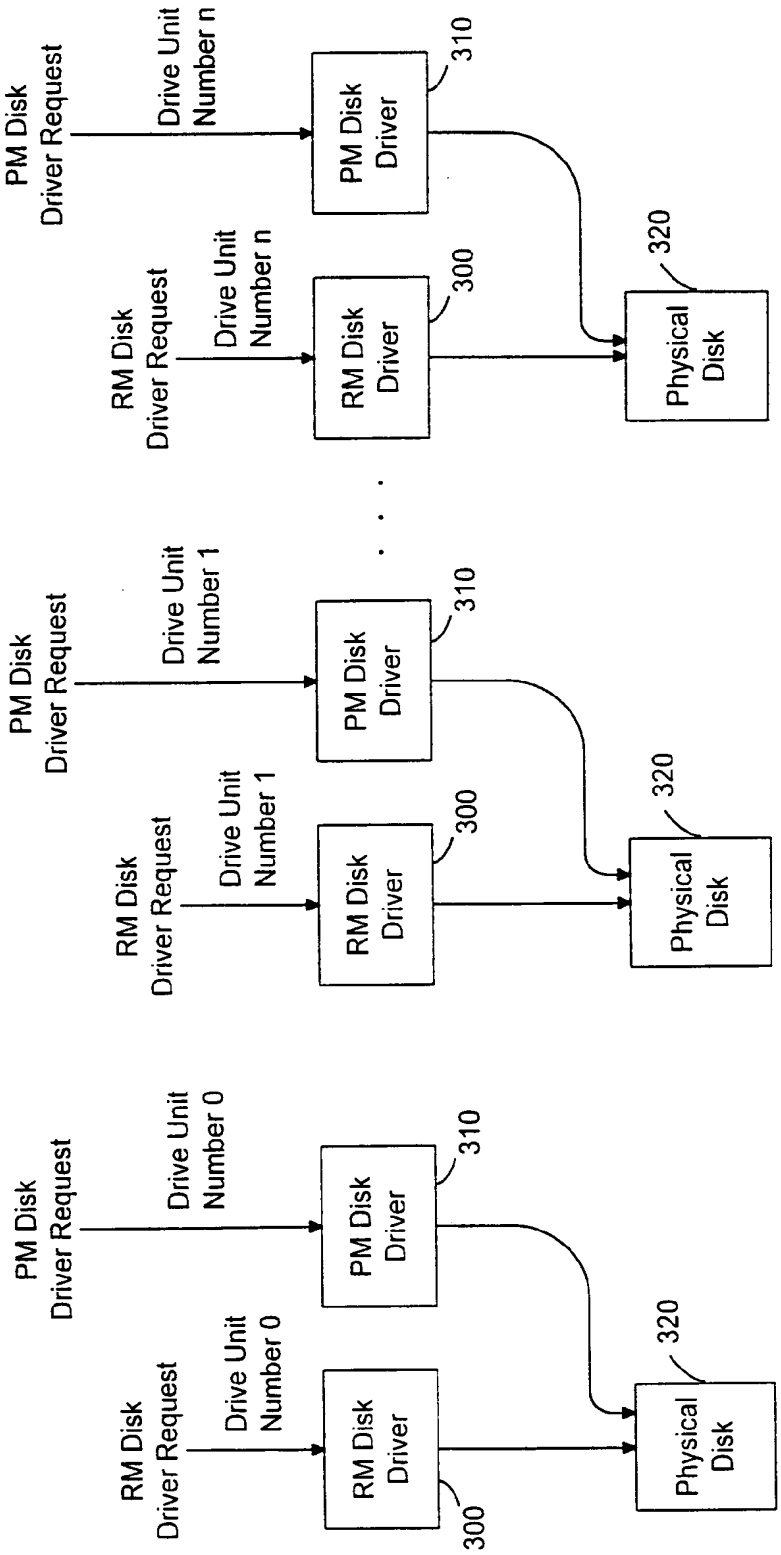

PM Disk
Driver Request
Drive Unit
Number 0
PM Disk
Driver
310
RM Disk
Driver Request
Drive Unit
Number 0
RM Disk
Driver
300
Physical
Disk
320
PM Disk
Driver Request
Drive Unit
Number 1
PM Disk
Driver
310
RM Disk
Driver Request
Drive Unit
Number 1
RM Disk
Driver
300
Physical
Disk
320
PM Disk
Driver Request
Drive Unit
Number n
PM Disk
Driver
310
RM Disk
Driver Request
Drive Unit
Number n
RM Disk
Driver
300
Physical
Disk
320

FIG. 3

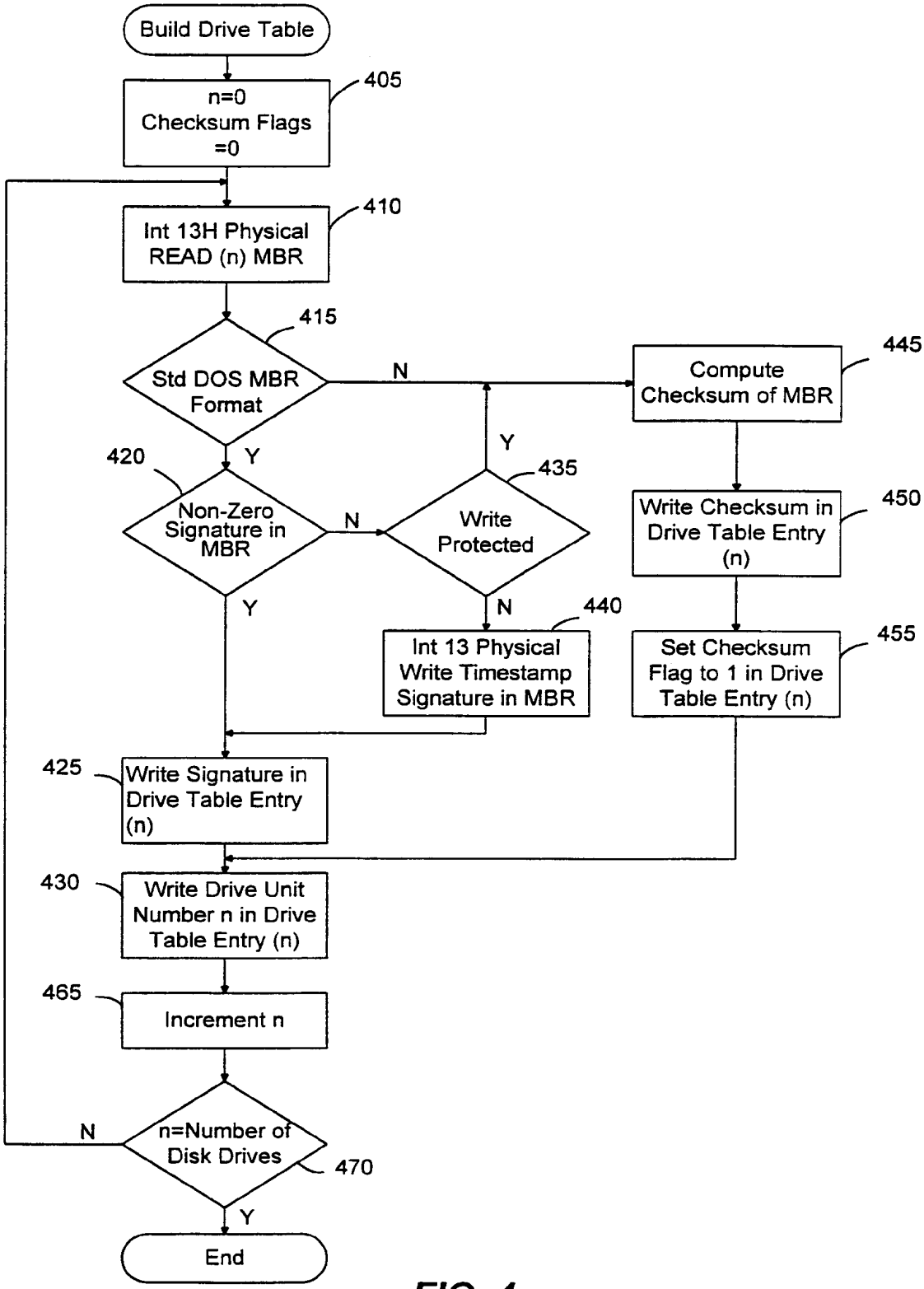

Build Drive Table
n=0
Checksum Flags
=0
405
Int 13H Physical
READ (n) MBR
410
Std DOS MBR
Format
415
N
Y
Compute
Checksum of MBR
445
420
Non-Zero
Signature in
MBR
N
Write
Protected
435
Y
Y
N
Write Checksum in
Drive Table Entry
(n)
450
440
Int 13 Physical
Write Timestamp
Signature in MBR
Set Checksum
Flag to 1 in Drive
Table Entry (n)
455
425
Write Signature in
Drive Table Entry
(n)
430
Write Drive Unit
Number n in Drive
Table Entry (n)
465
Increment n
N
n=Number of
Disk Drives
470
Y
End

FIG. 4

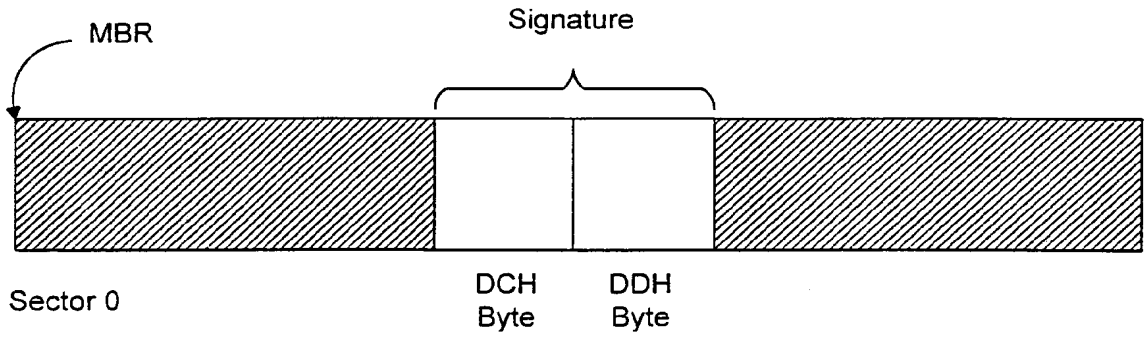


FIG. 5

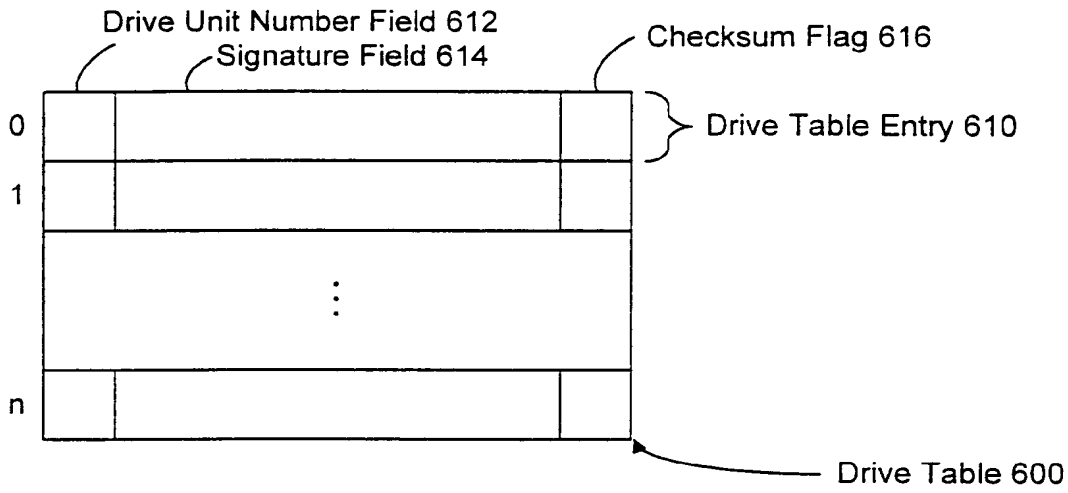

Drive Unit Number Field 612
Signature Field 614
Checksum Flag 616
0
1
n
Drive Table Entry 610
Drive Table 600

FIG. 6

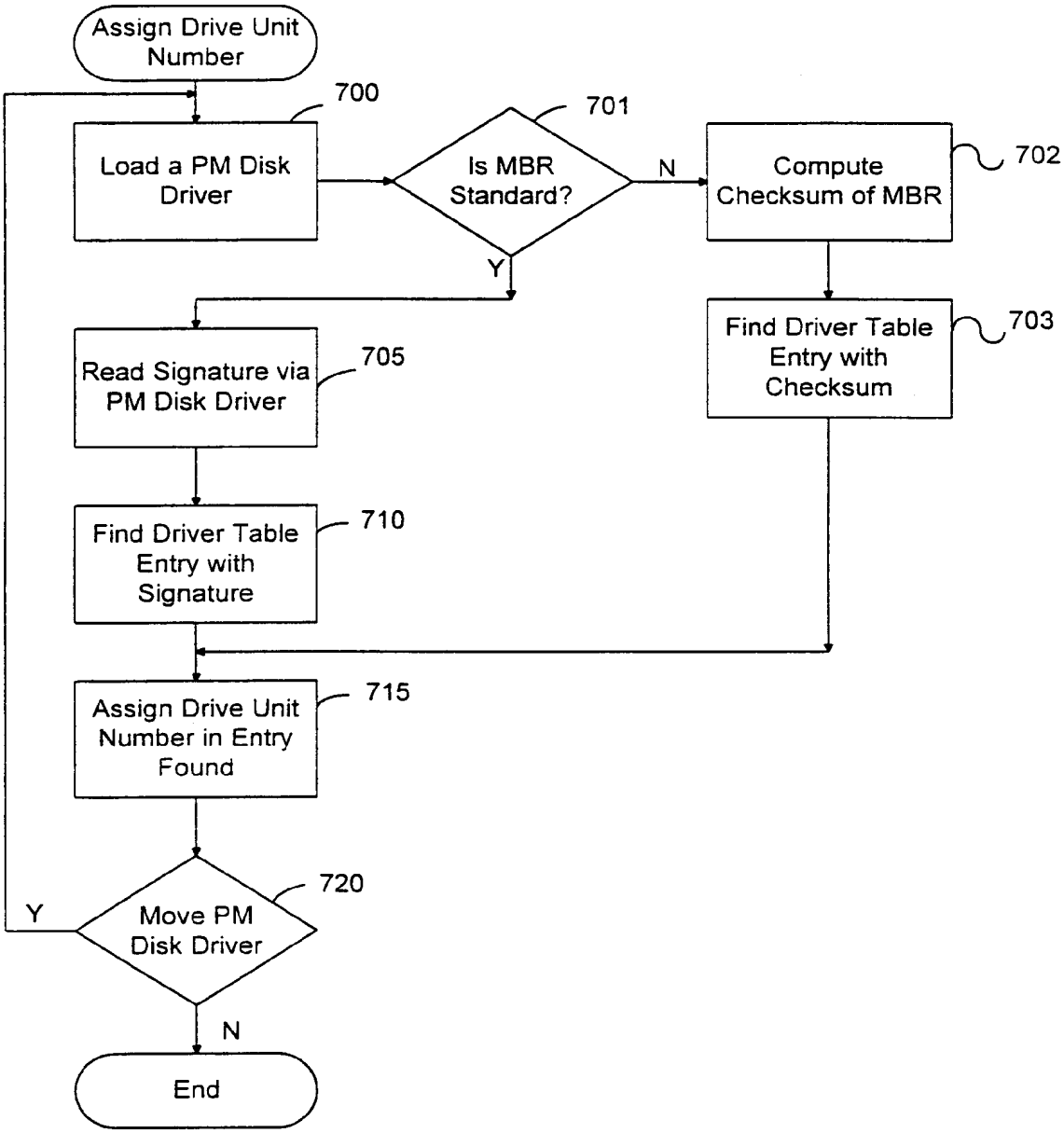

Assign Drive Unit Number
700
Load a PM Disk Driver
701
Is MBR Standard?
N
Compute Checksum of MBR
702
Y
Find Driver Table Entry with Checksum
703
Read Signature via PM Disk Driver
705
Find Driver Table Entry with Signature
710
Assign Drive Unit Number in Entry Found
715
720
Y
Move PM Disk Driver
N
End

FIG. 7

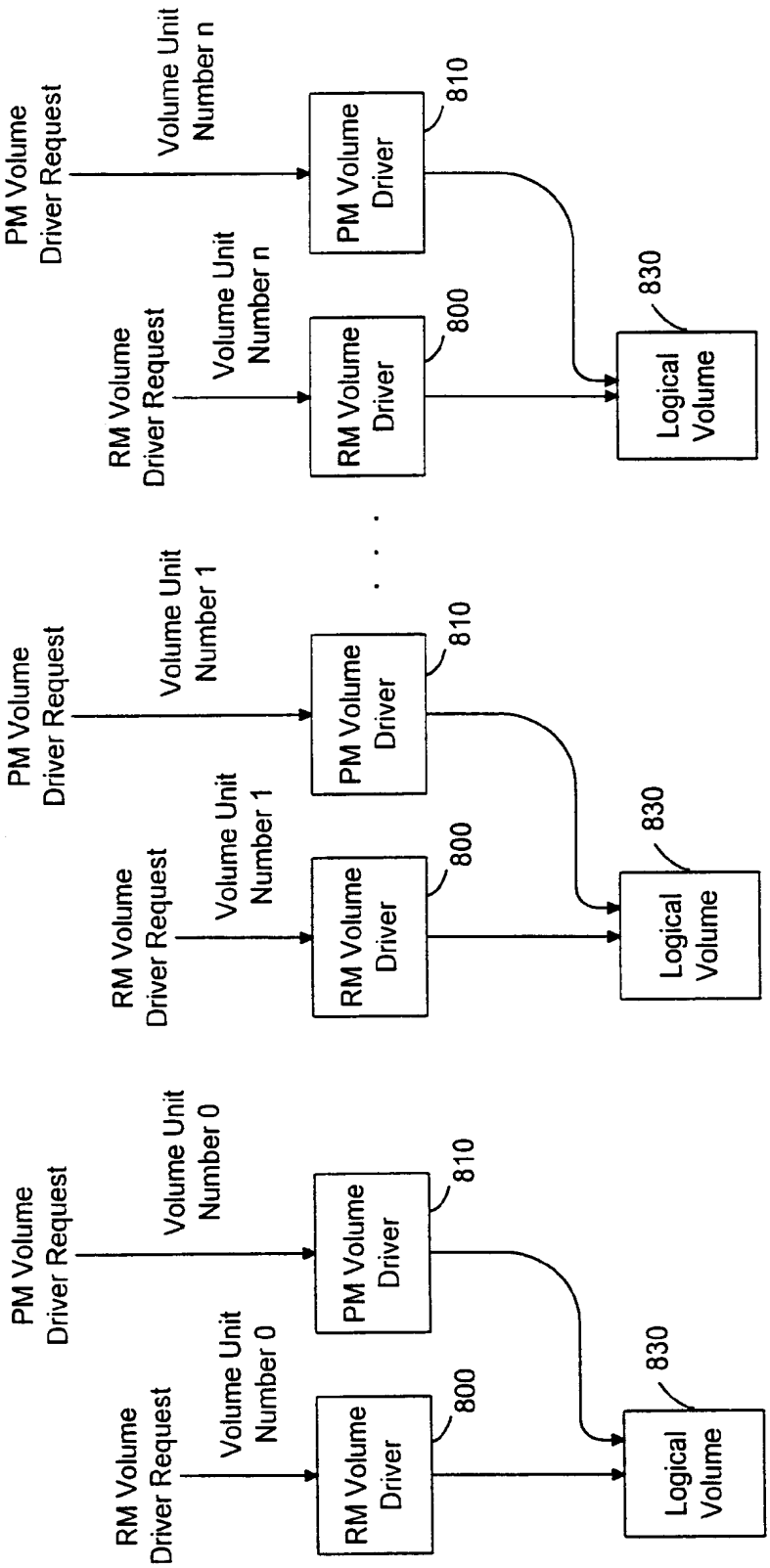

PM Volume Driver Request
Volume Unit Number 0
RM Volume Driver Request
Volume Unit Number 0
PM Volume Driver
RM Volume Driver
810
800
Logical Volume
830
PM Volume Driver Request
Volume Unit Number 1
RM Volume Driver Request
Volume Unit Number 1
PM Volume Driver
RM Volume Driver
810
800
Logical Volume
830
PM Volume Driver Request
Volume Unit Number n
RM Volume Driver Request
Volume Unit Number n
PM Volume Driver
RM Volume Driver
810
800
Logical Volume
830

FIG. 8

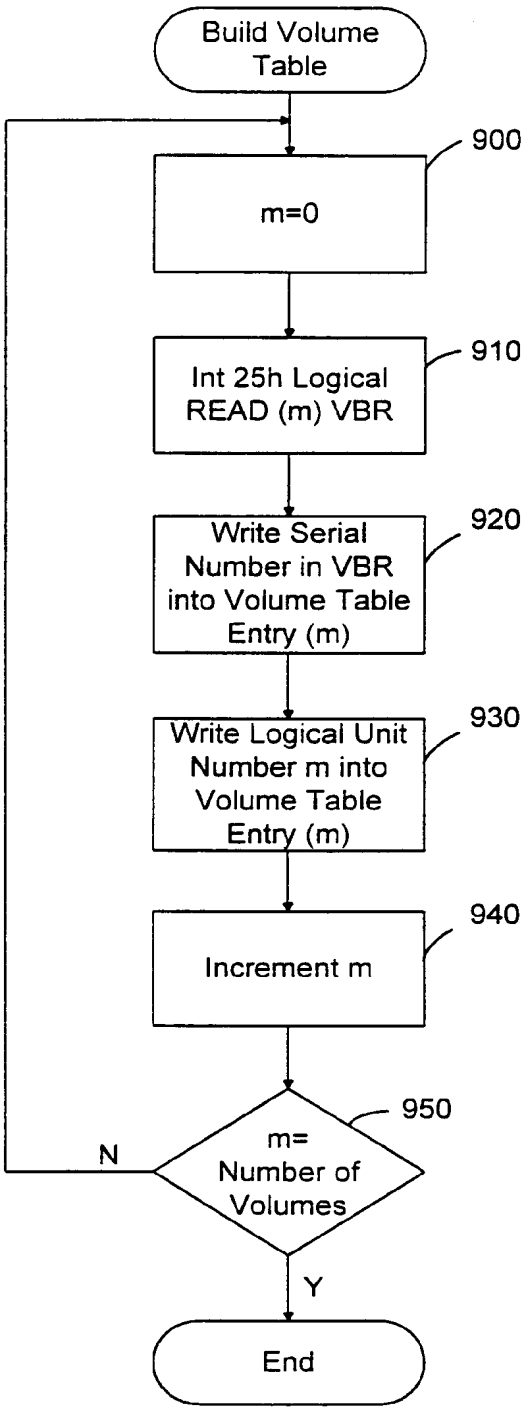

Build Volume Table
900
m=0
910
Int 25h Logical READ (m) VBR
920
Write Serial Number in VBR into Volume Table Entry (m)
930
Write Logical Unit Number m into Volume Table Entry (m)
940
Increment m
950
m= Number of Volumes
N
Y
End

FIG. 9

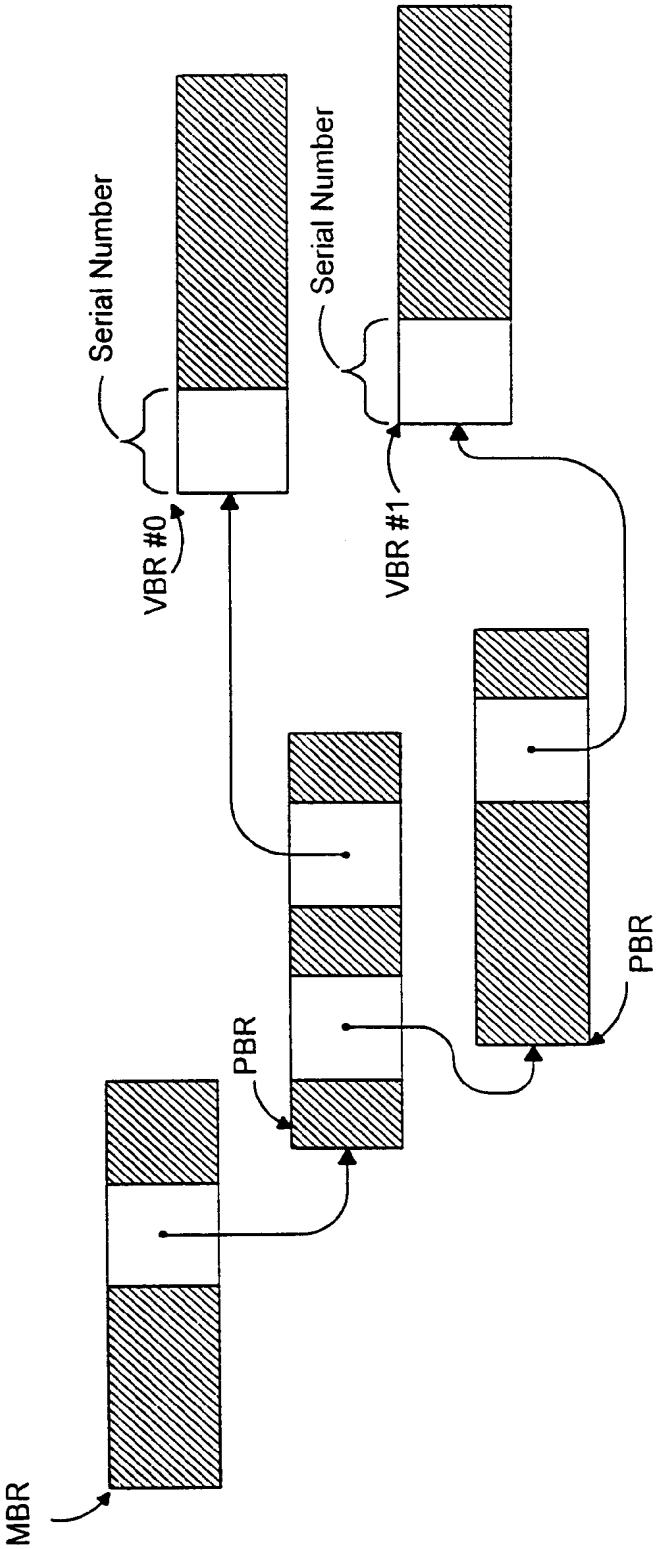


FIG. 10

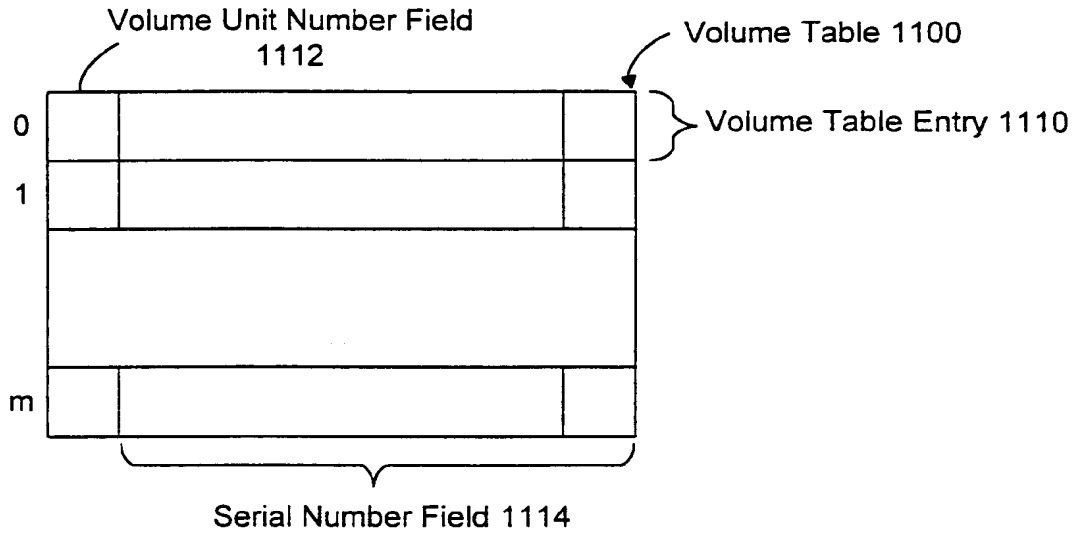

Volume Unit Number Field
1112
Volume Table 1100
0
1
m
Volume Table Entry 1110
Serial Number Field 1114

FIG. 11

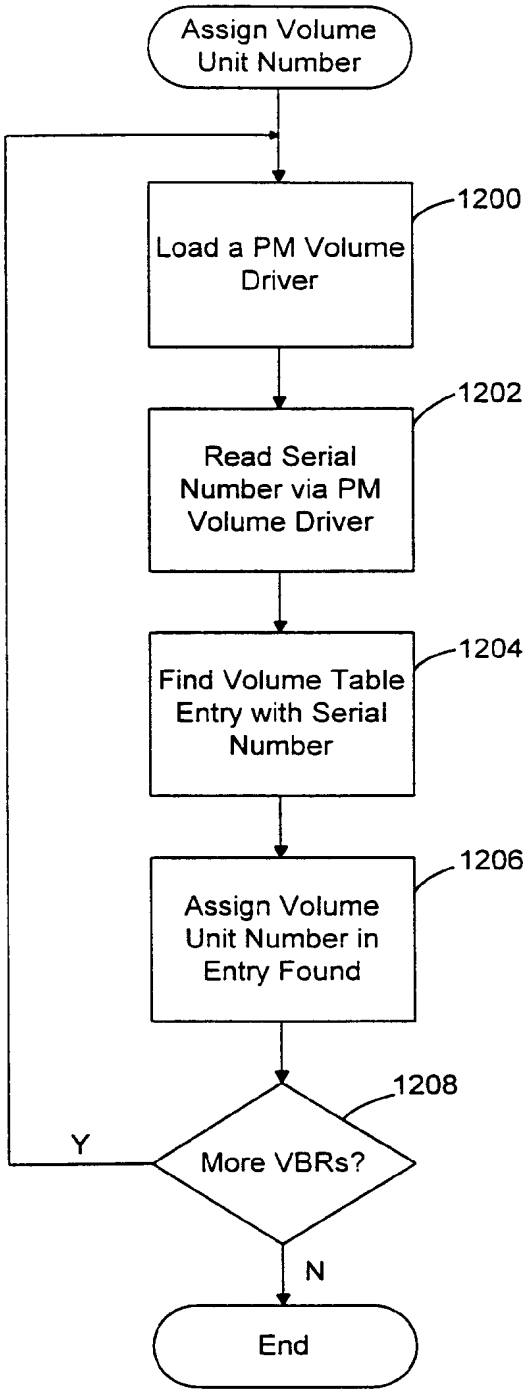

Assign Volume Unit Number
1200
Load a PM Volume Driver
1202
Read Serial Number via PM Volume Driver
1204
Find Volume Table Entry with Serial Number
1206
Assign Volume Unit Number in Entry Found
1208
More VBRs?
Y
N
End

FIG. 12

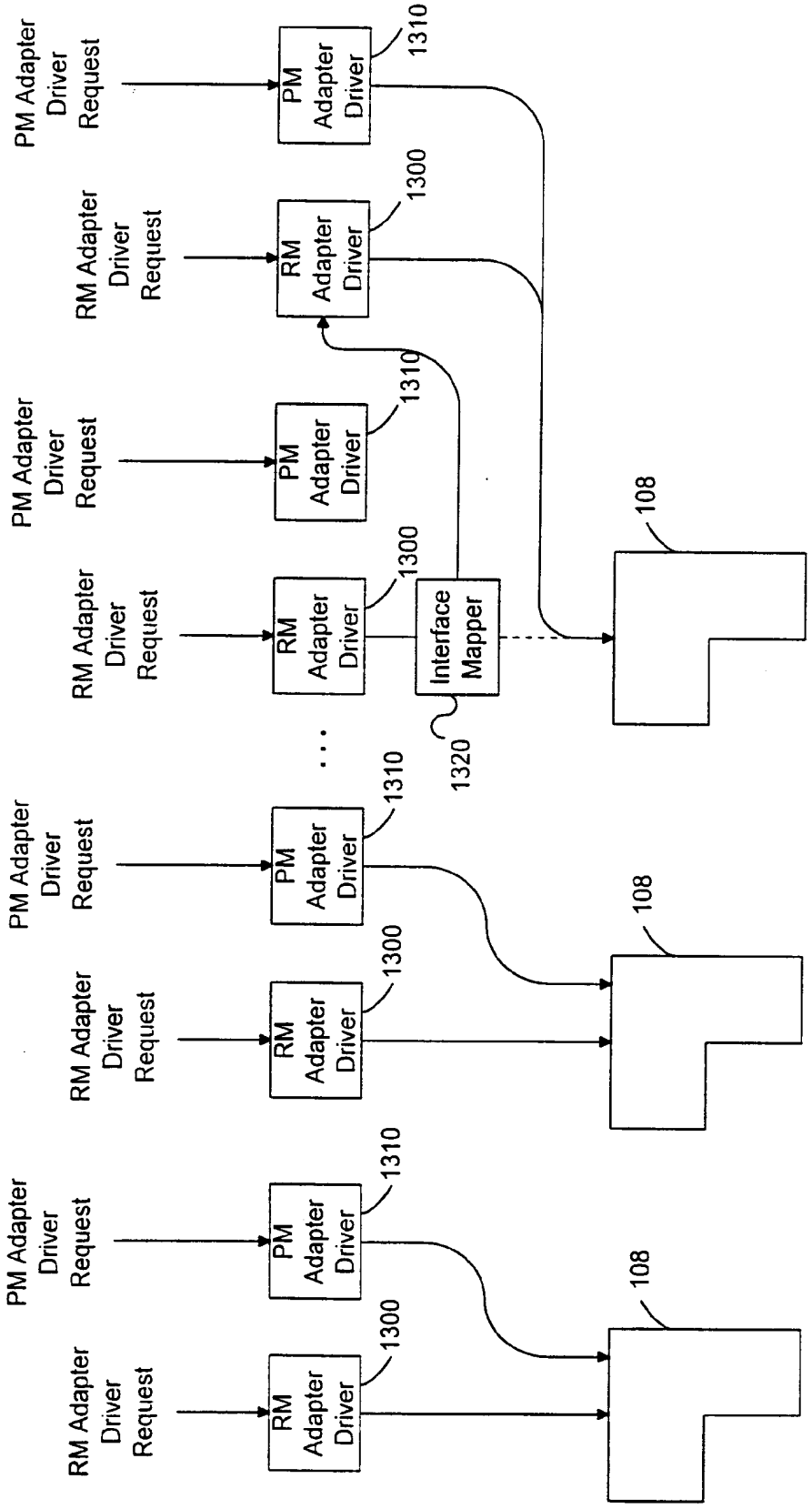
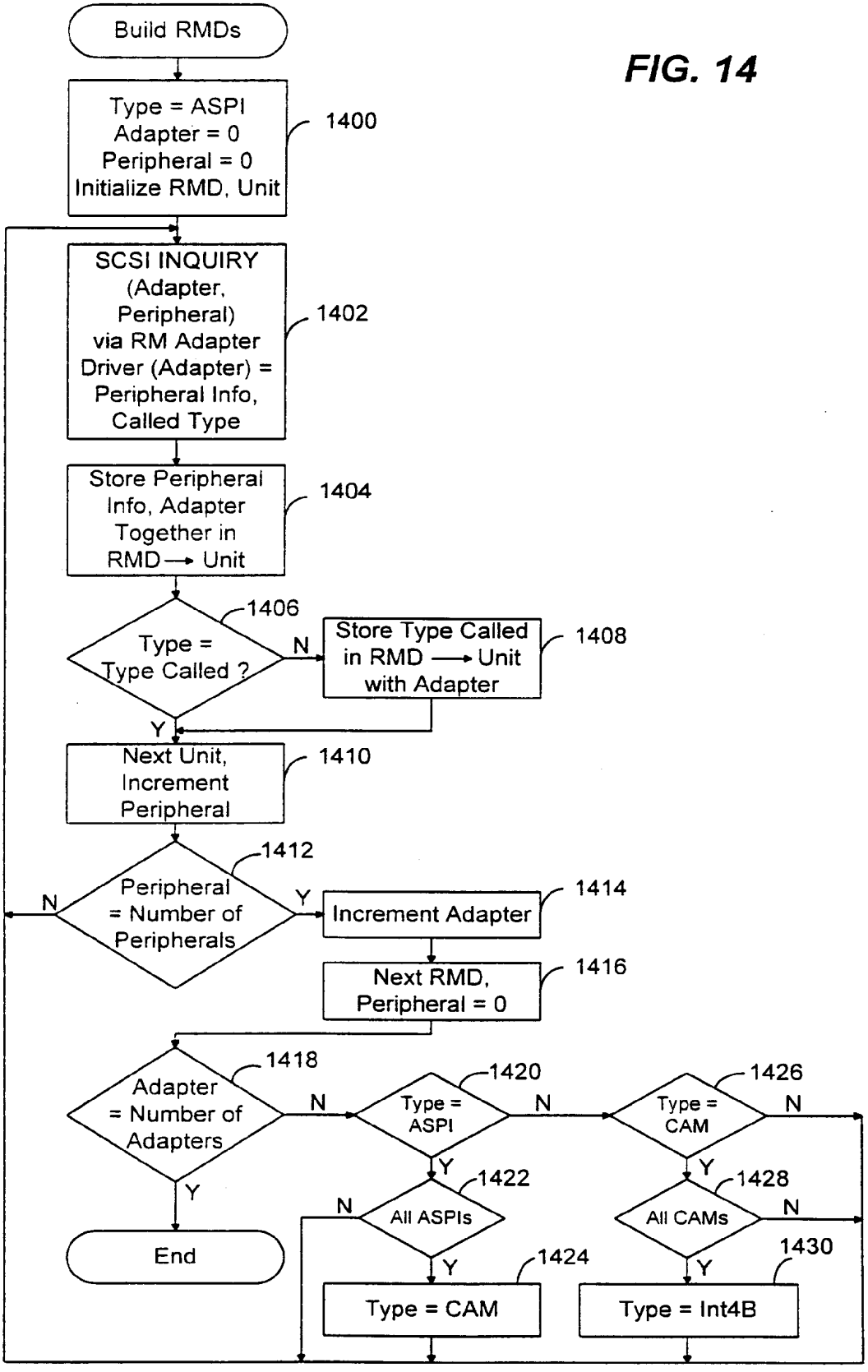

PM Adapter Driver Request
RM Adapter Driver Request
PM Adapter Driver
RM Adapter Driver
Interface Mapper
1310
1300
1320
108

FIG. 13

FIG. 14


Build RMDs
Type = ASPI
Adapter = 0
Peripheral = 0
Initialize RMD, Unit
1400
SCSI INQUIRY (Adapter, Peripheral) via RM Adapter Driver (Adapter) = Peripheral Info, Called Type
1402
Store Peripheral Info, Adapter Together in RMD → Unit
1404
1406
Type = Type Called ?
N
Store Type Called in RMD → Unit with Adapter
1408
Y
Next Unit, Increment Peripheral
1410
1412
Peripheral = Number of Peripherals
N
Y
Increment Adapter
1414
Next RMD, Peripheral = 0
1416
1418
Adapter = Number of Adapters
N
1420
Type = ASPI
N
1426
Type = CAM
N
Y
Y
Y
1422
All ASPIs
N
1428
All CAMs
N
End
Y
Y
1424
Type = CAM
1430
Type = Int4B

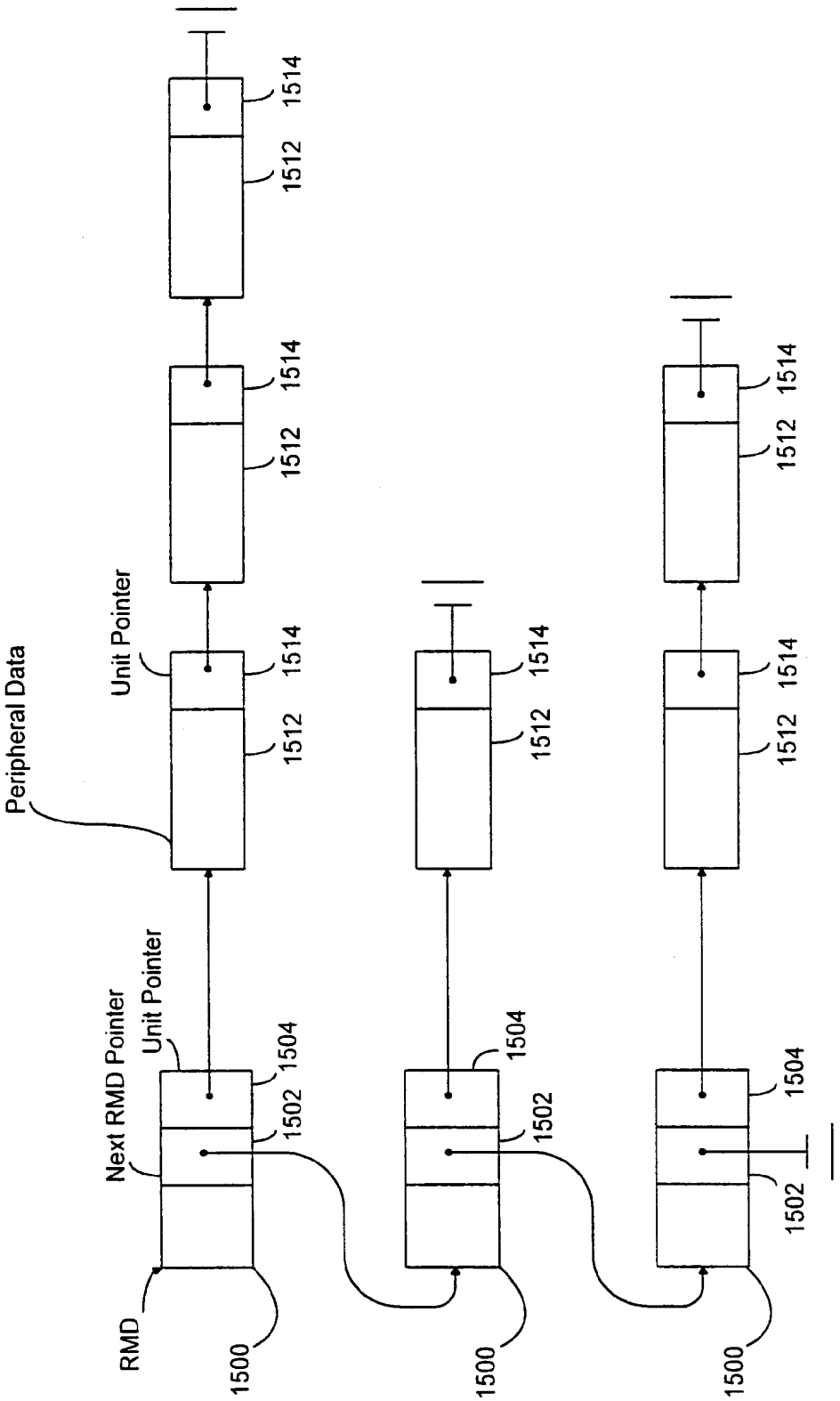

Peripheral Data
Unit Pointer
Next RMD Pointer
Unit Pointer
RMD
1500
1502
1504
1512
1514

FIG. 15

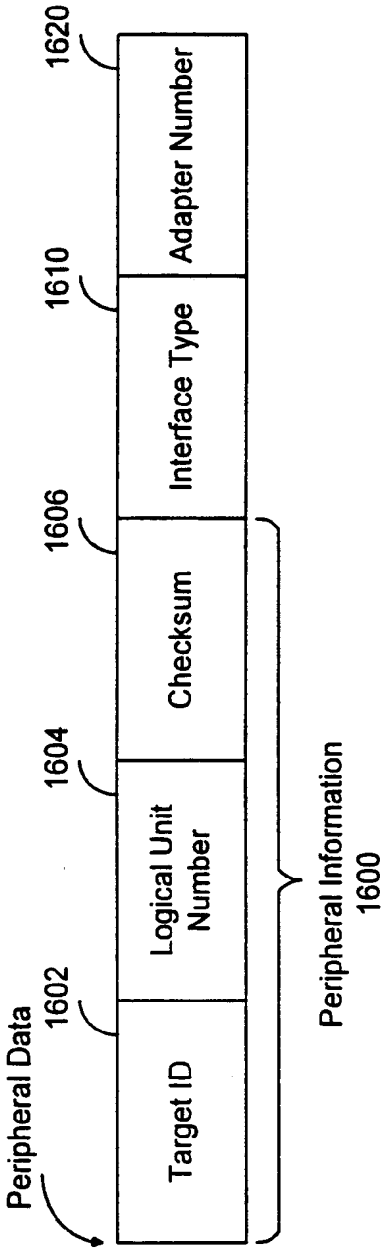

Peripheral Data
1602
Target ID
1604
Logical Unit Number
1606
Checksum
1610
Interface Type
1620
Adapter Number
Peripheral Information
1600

FIG. 16

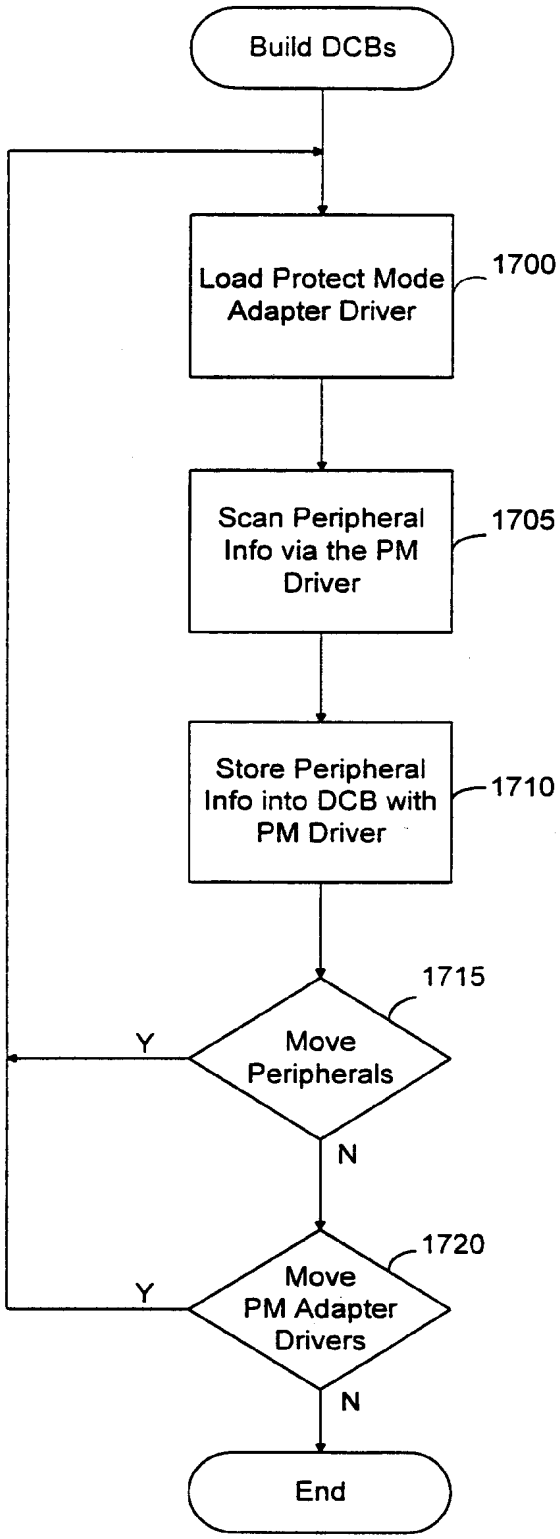

Build DCBs
Load Protect Mode Adapter Driver
1700
Scan Peripheral Info via the PM Driver
1705
Store Peripheral Info into DCB with PM Driver
1710
1715
Move Peripherals
Y
N
1720
Move PM Adapter Drivers
Y
N
End

FIG. 17

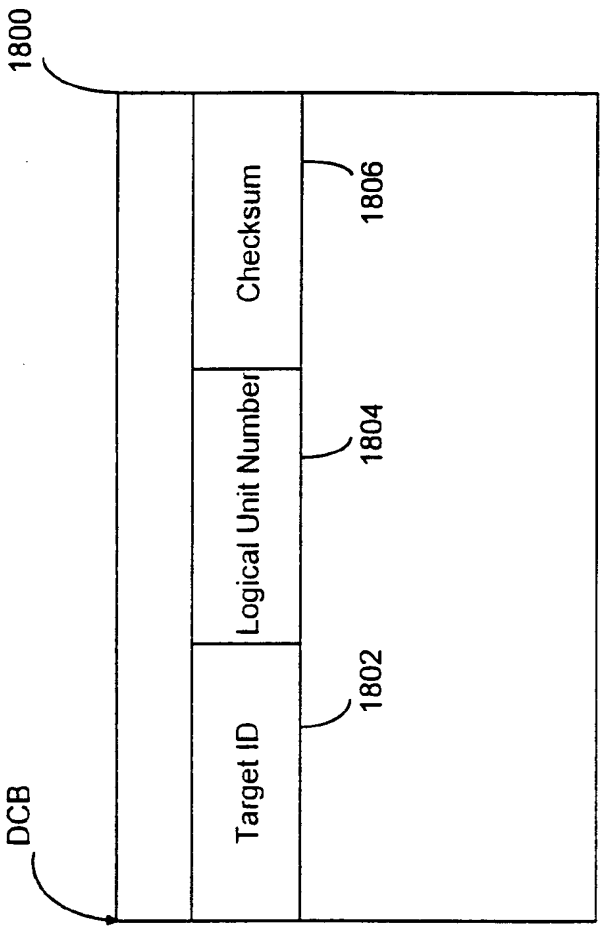

1800
DCB
Target ID
Logical Unit Number
Checksum
1802
1804
1806

FIG. 18

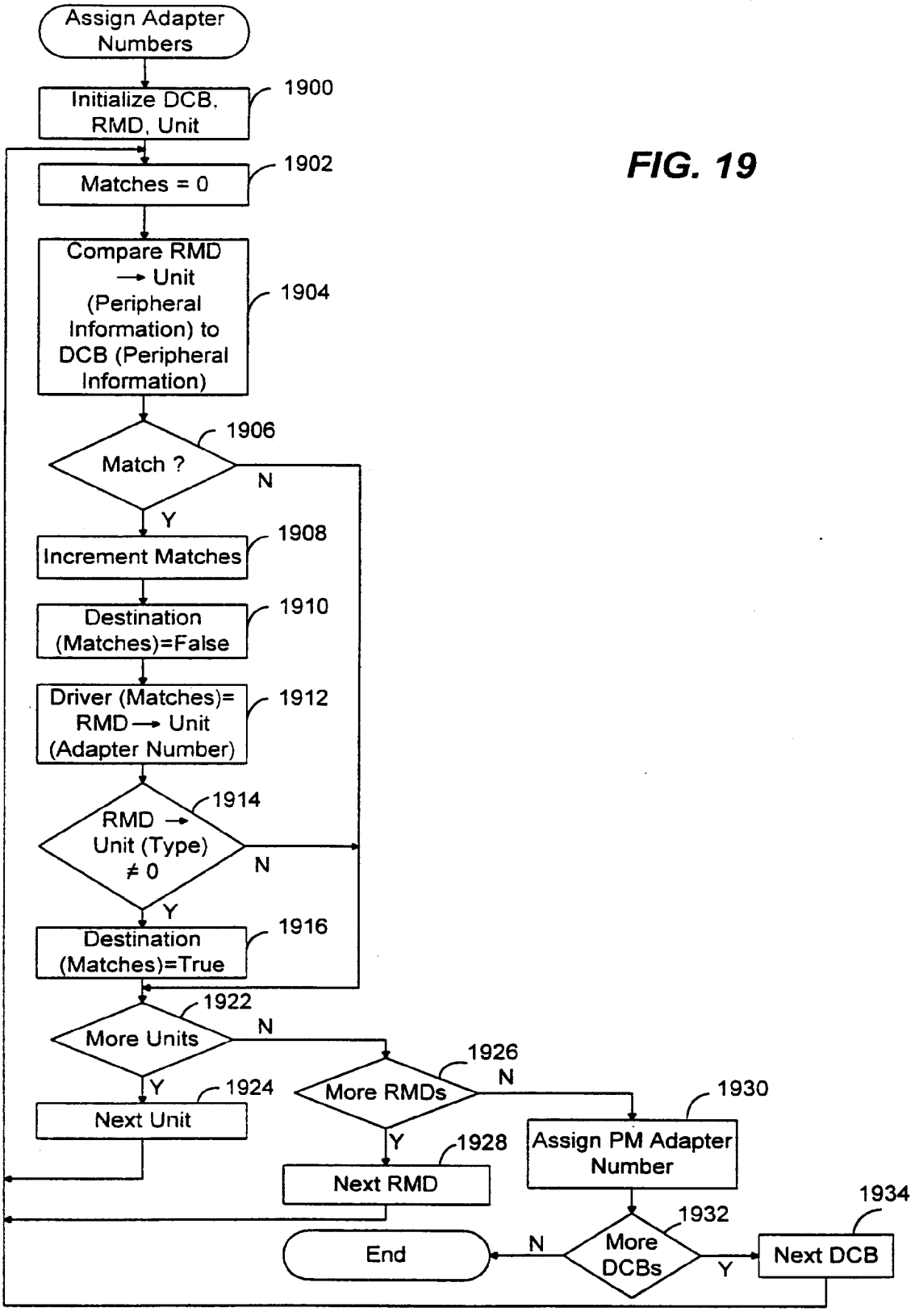

Assign Adapter Numbers
Initialize DCB, RMD, Unit
1900
Matches = 0
1902
Compare RMD → Unit (Peripheral Information) to DCB (Peripheral Information)
1904
Match ?
1906
N
Y
Increment Matches
1908
Destination (Matches)=False
1910
Driver (Matches)= RMD → Unit (Adapter Number)
1912
RMD → Unit (Type) ≠ 0
1914
N
Y
Destination (Matches)=True
1916
More Units
1922
N
Y
Next Unit
1924
More RMDs
1926
N
Y
Next RMD
1928
Assign PM Adapter Number
1930
More DCBs
1932
N
Y
Next DCB
1934
End

FIG. 19

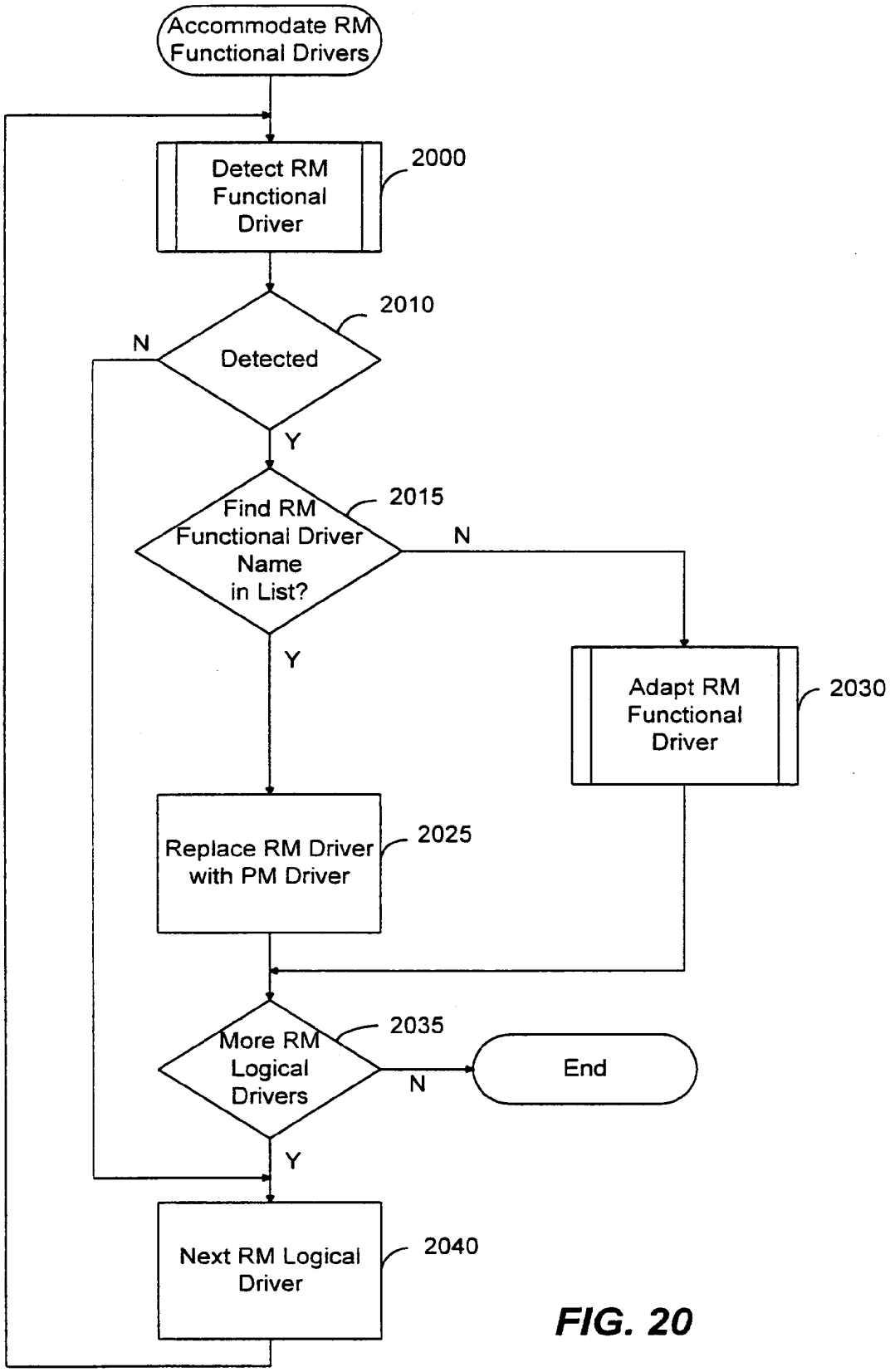

Accommodate RM Functional Drivers
Detect RM Functional Driver
2000
Detected
2010
N
Y
Find RM Functional Driver Name in List?
2015
N
Y
Adapt RM Functional Driver
2030
Replace RM Driver with PM Driver
2025
More RM Logical Drivers
2035
N
End
Y
Next RM Logical Driver
2040

FIG. 20

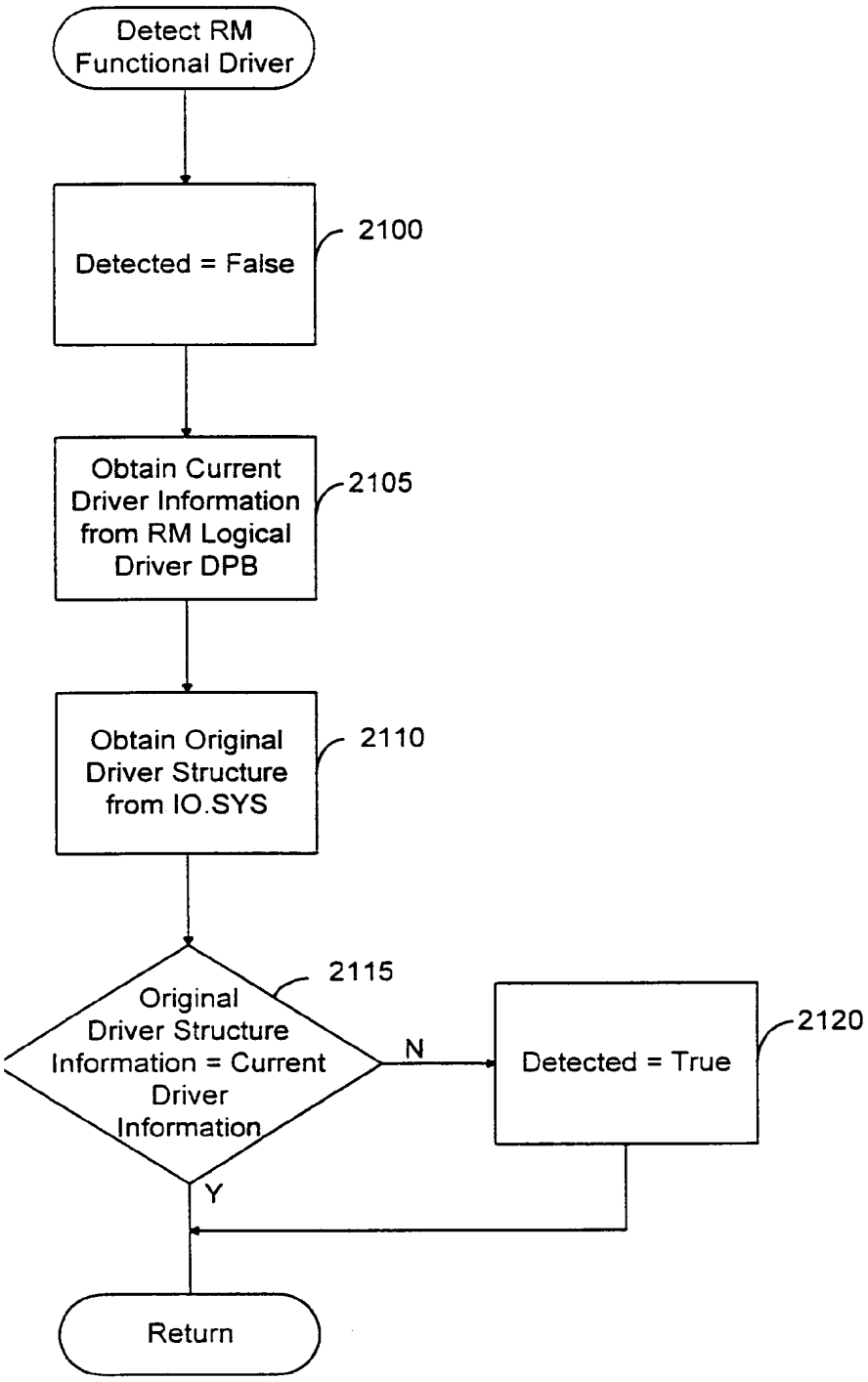

Detect RM Functional Driver
Detected = False
2100
Obtain Current Driver Information from RM Logical Driver DPB
2105
Obtain Original Driver Structure from IO.SYS
2110
Original Driver Structure Information = Current Driver Information
2115
N
Detected = True
2120
Y
Return

FIG. 21

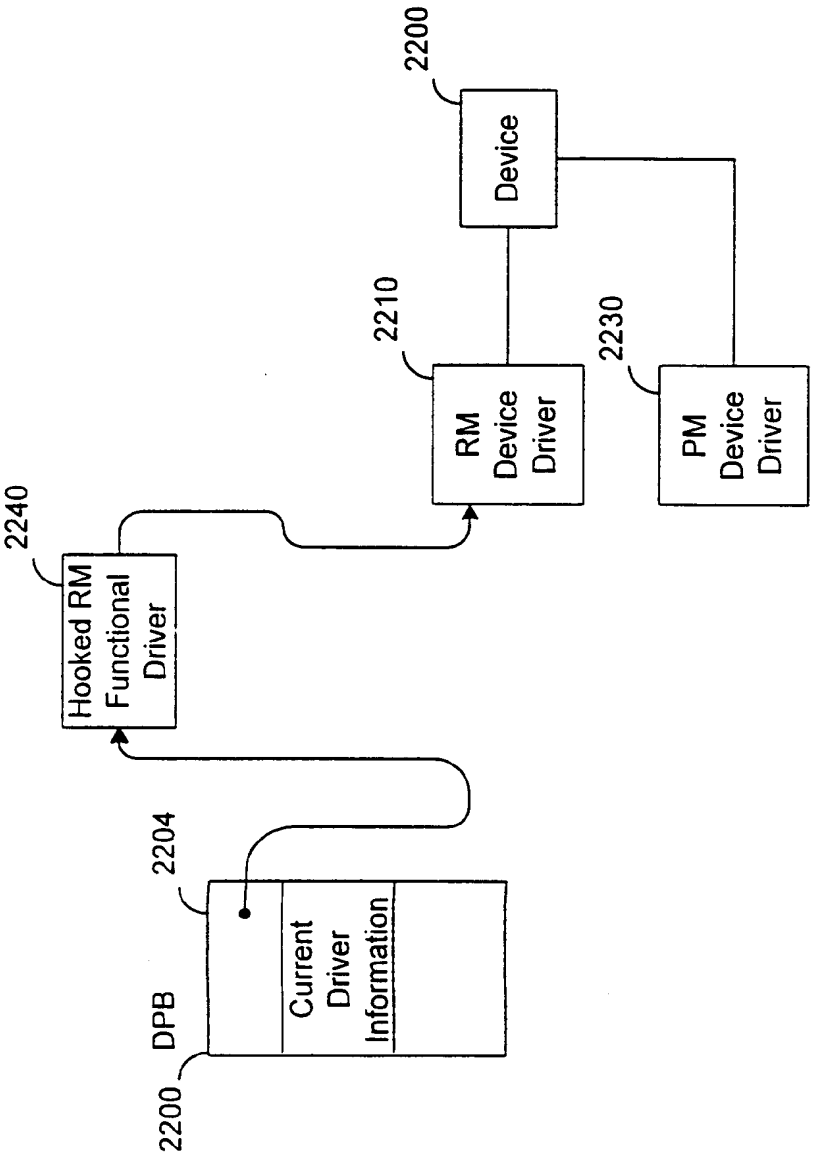

2200
Device
2210
RM
Device
Driver
2230
PM
Device
Driver
2240
Hooked RM
Functional
Driver
2204
DPB
Current
Driver
Information
2200

FIG. 22

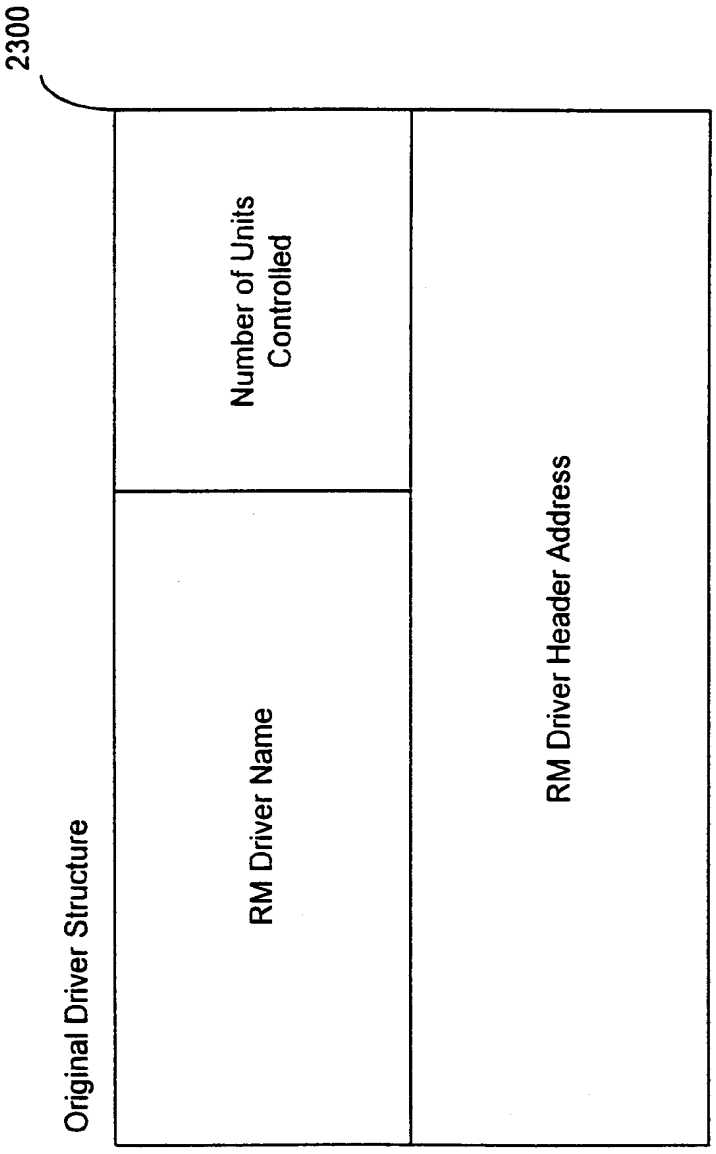

2300
Original Driver Structure
RM Driver Name
Number of Units Controlled
RM Driver Header Address

FIG. 23

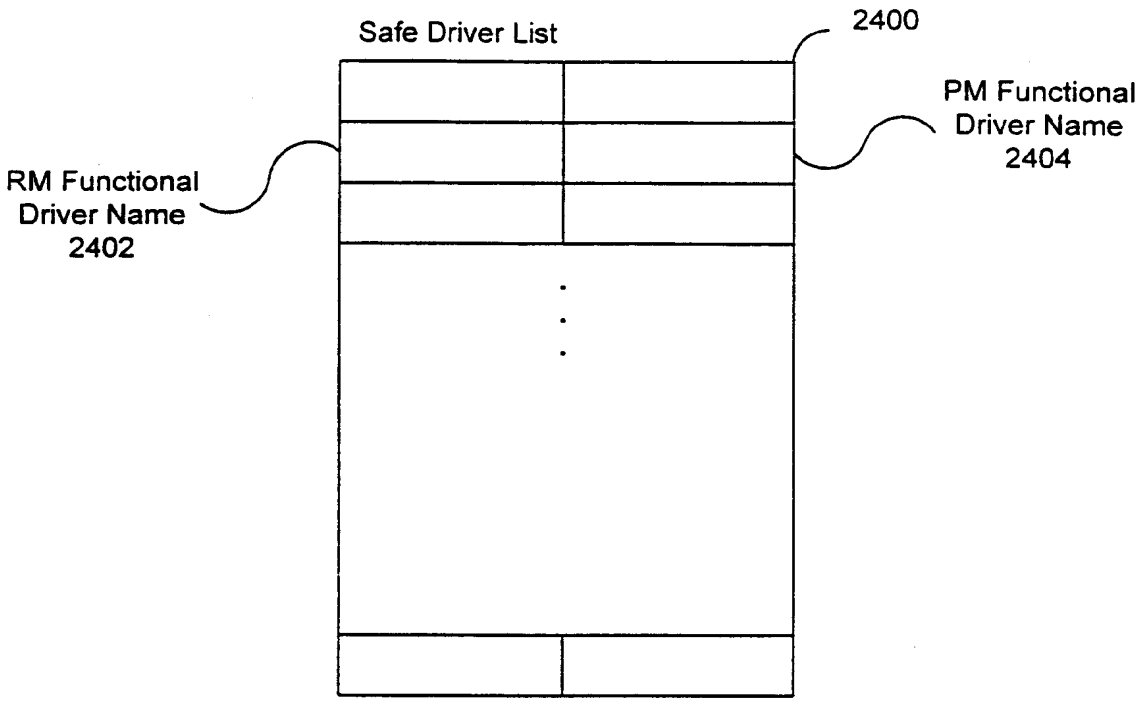

Safe Driver List
2400
PM Functional Driver Name 2404
RM Functional Driver Name 2402

FIG. 24

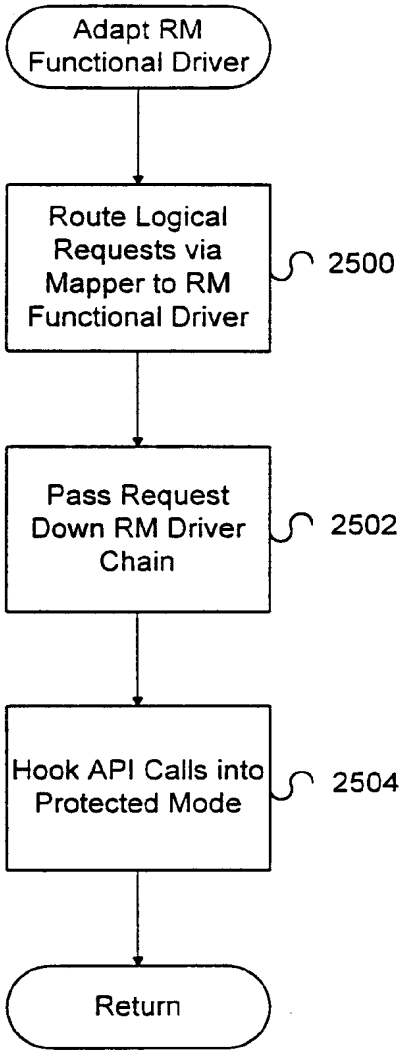

Adapt RM Functional Driver
Route Logical Requests via Mapper to RM Functional Driver
2500
Pass Request Down RM Driver Chain
2502
Hook API Calls into Protected Mode
2504
Return

FIG. 25

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 664 507 A3

(12) EUROPEAN PATENT APPLICATION

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(43) Date of publication A2:
26.07.1995 Bulletin 1995/30

(21) Application number: **95100566.9**

(22) Date of filing: **17.01.1995**

(51) Int Cl.[7]: **G06F 3/06**, G06F 9/455, G06F 13/10

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DE FR GB

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  Bellevue, Washington 98006 (US)

(74) Representative: **Grünecker, Kinkeldey,**
Stockmair & Schwanhäusser Anwaltssozietät
Maximilianstrasse 58
80538 München (DE)

(54) Method and system for providing protected mode device drivers

(57) A computer method and system for providing protected mode device drivers that are compatible with real mode device drivers. A first aspect of the invention provides consistent assignment of drive unit numbers with which the same physical disks are accessed by the real mode and protected mode physical disk drivers. A second aspect of the invention provides consistent assignment of volume unit numbers with which the same logical volumes are accessed by real mode and protected mode logical volume drivers. A third aspect of the invention provides consistent assignment of adapter numbers with which the same adapters are controlled by real mode and protected mode adapter drivers and mapping real mode adapter driver requests to protected mode adapter driver requests of the protected mode adapter drivers that control the same adapters. A fourth aspect of the invention provides detection and protected mode accommodation of real mode functional drivers which are provided in addition to the real mode device drivers in the real mode operating system.

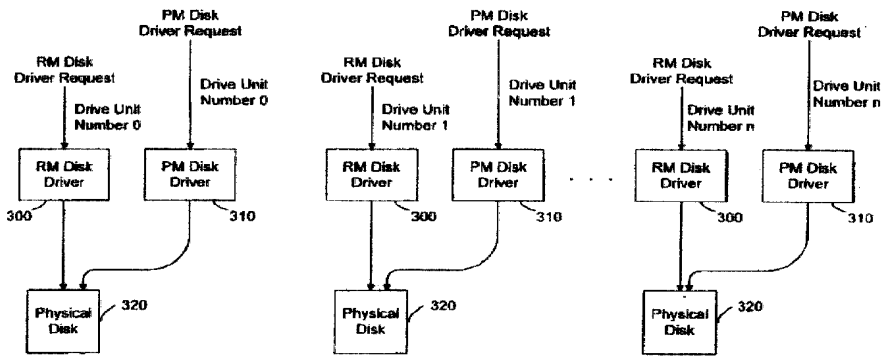

FIG. 3

EP 0 664 507 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 10 0566

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 288 606 A (IBM) 2 November 1988 (1988-11-02) * column 4, line 31 - column 5, line 52; figure 6 *	1,3,10, 13,21, 27,34	G06F3/06 G06F9/455 G06F13/10
A	EP 0 499 394 A (IBM) 19 August 1992 (1992-08-19) * page 2, line 35 - page 3, line 3 *	1,3,10, 13,21, 27,34	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
G06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	5 October 2001	Moens, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
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EPO FORM 1503 03.82 (P04C01)

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05-10-2001

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		DE 3786660 T2	17-02-1994
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		EP 0288606 A2	02-11-1988
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		JP 1998292 C	08-12-1995
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		JP 63244147 A	11-10-1988
		NL 8800736 A ,C	17-10-1988
		SG 5792 G	20-03-1992
		US 5193161 A	09-03-1993
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		EP 0499394 A1	19-08-1992
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		JP 7066354 B	19-07-1995

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